January–June, 2020

Vol. 59, Nos. 1–2

THE GREAT LAKES BOTANIST

A Journal of North American Botany

The Great Lakes Botanist Vol. 59, Nos. 1–2 January–July 2020

THE GREAT LAKES BOTANIST (ISSN 2576-8727), formerly THE MICHIGAN BOTANIST (ISSN 0026-203X), is published four times per year by the Michigan Botanical Club (www.michbotclub.org) and is available online at http://quod.lib.umich.edu/m/mbot/. The subscription rate is $25.00 per year. Periodicals postage paid at Ann Arbor, MI 48103.

THE GREAT LAKES BOTANIST publishes papers on all aspects of the natural history of plants of North America north of Mexico, including systematics, floristics, ecology, conservation, botanical history, economic botany and ethnobotany, restoration, and other areas of organismal botany. Plant groups include vascular plants, bryophytes, fungi, and algae. The journal maintains the Great Lakes region as one area of special focus. The Great Lakes region is defined as the entirety of the states and provinces bordering any of the Great Lakes, that is, Michigan, Wisconsin, Minnesota, Illinois, Indiana, Ohio, Ontario, Pennsylvania, and New York.

On all editorial matters, please contact the Editor, Michael Huft, 232 Akela Dr., Valparaiso, IN 46385. Phone: (847) 682-5240; email: mhuft@att.net. All articles dealing with botany in North America may be sent to the Editor at the above address. In preparing manuscripts, authors are requested to follow the "Instructions to Authors" on the inside back cover and, more fully, at http://quod.lib.umich.edu/m/mbot/submit.

For all inquiries about back issues and institutional subscriptions, please contact The Great Lakes Botanist Business Office, 232 Akela Dr., Valparaiso, IN 46385. Phone: (224) 420-0326; email: michbot.business@gmail.com.

THE MICHIGAN BOTANICAL CLUB

Membership is open to anyone interested in its aims: conservation of all native plants; education of the public to appreciate and preserve plant life; sponsorship of research and publication on plant life; sponsorship of legislation to promote the preservation of Michigan's native flora; establishment of suitable sanctuaries and natural areas, and cooperation in programs concerned with the wise use and conservation of all natural resources and scenic features.

Dues are modest, but vary slightly among the chapters. To become a chapter member please contact the chapter presidents listed below. Annual dues include a subscription to *The Michigan Botanist*. Address changes for Chapter Members should go to the Chapter President.

Vol. 58, Nos. 3–4 was mailed May 27, 2020.

ANALYZING VEGETATIVE COVER OF THE BOIS BRULE RIVER WATERSHED RE-VISITED IN NORTHWESTERN WISCONSIN, PART I: FOREST STAND CHANGES (1968 TO 2016)[1]

Paul S. Hlina[2], Derek S. Anderson, Reed J. Schwarting

Lake Superior Research Institute
University of Wisconsin-Superior
Barstow Hall 4, Belknap and Catlin Ave., P.O. Box 2000
Superior, WI 54880

Mary Ann E. Feist

Wisconsin State Herbarium
University of Wisconsin-Madison
Department of Botany, Birge Hall
430 Lincoln Drive
Madison, WI 53706

ABSTRACT

The Bois Brule River flows through some of the most diverse habitats found anywhere in Wisconsin. In 2015 and 2016, our survey teams were able to collect and analyze forest strata data from 48 of the 54 forest stands surveyed by Davidson in 1968–69 using the point-centered quarter sampling method. Stands were dominated by transitional forest of northern hardwoods, while some forest types were represented by only one stand each. Average absolute tree density decreased by 25% over the 48 years, while the tree basal area did not change much with a slight decrease of 6%. These changes were indicative of a later successional stage of these forests. Species showing significant change are *Betula papyrifera*, *Abies balsamea* and *Acer rubrum*. Old growth forests have entered a later stage of maturity with some *Pinus strobus* individuals becoming snags today and *P. resinosa* trees becoming larger. Our sapling surveys in these old growth forests suggest *Acer rubrum* and *Abies balsamea* could become dominant forests in the future, with little or no recruitment from the pines. Our survey depicts a forest that is trending to a later successional stage of development and recovering from the cutover from the early 20th century. Future threats to these forests include disruptions in the natural fire regime, non-native plants (e.g., *Rhamnus cathartica*, *Lonicera* spp.), insect infestations (e.g., *Choristoneura fumiferana*, *Agrilus planipennis*), excessive fragmentation from harvesting activities and climate change. These forests may exhibit some resiliency to climate change due to the watershed's proximity to Lake Superior and the river's deep valley.

KEYWORDS: Flora of Wisconsin, land change, pre-settlement conditions, Brule River Survey, northern forest community types

INTRODUCTION

This is the first of two articles (the second of which is Hlina et al. 2020) reporting on a three-year project to re-survey and analyze vegetative and land use

---

[1] Data sets used in this article are available upon request from the Lake Superior Research Institute at the University of Wisconsin-Superior, Superior, Wisconsin.

[2] Author for correspondence (phlina4@gmail.com)

changes in the exceptional Bois Brule River watershed in northwestern Wisconsin over the last 160 years. The original survey resulted from a call by the University of Wisconsin and the Wisconsin Conservation Department in 1942 for an extensive study and evaluation of the physical, biological and chemical characteristics of the watershed, resulting over the next several years in 11 separate monographs, featuring environmental factors that would better explain the causes of declining fish populations in the river. The study was called the Brule River Survey. Dr. Norman Fassett and Dr. John Thomson oversaw three portions of the study by assessing and describing the vegetation of the Brule River Gorge, its forest and wetland communities and provided a detailed vegetative mapping effort of the Brule River Watershed from 1852 to 1944.

In 1968, Dr. Donald W. Davidson, a plant scientist at the University of Wisconsin-Superior, started a re-survey of the Fassett and Thomson's vegetative studies by focusing on trees and saplings in 54 forest stands throughout the watershed. Though this work was never published, the original data with maps exists and contains significant information concerning the Brule River forests. The Davidson study closely follows the same study areas as the 1942–1944 study, though there were insufficient resources to complete the other stratum in the forests (e.g., shrub and herbaceous), aquatic vegetation of the river, and other wetland communities.

An Opportunity to Study Forest Change

Although we generally know about regional changes in the forest since EuroAmerican settlement through public land survey records (Schulte and Mladenoff 2001, Schulte et.al. 2002, Kronenfeld and Wang 2007), it is uncommon to have high-quality data from earlier times that could be used to make quantitative comparisons of forest change. An opportunity arose, however, in the autumn of 2014, when, during a routine office cleaning at the Brule River State Forest, Wisconsin, a cardboard box was discovered that contained hand written notes, completed raw data sheets, and topographic maps of an extensive forest survey of the Brule River watershed conducted in 1968 and 1969 by Dr. Donald W. Davidson of the University of Wisconsin-Superior. Davidson was a locally renowned botany professor who had passed away in early 2014. The lead author was made aware of this work and the materials were returned to the University of Wisconsin-Superior. The papers provided raw forest inventory data for 54 forest stands in the Brule River watershed in northwestern Wisconsin and provided the inspiration for us to undertake a re-survey of these stands. The watershed is located 48 km east of Superior, Wisconsin and the town of Brule is in the middle reaches of the river and watershed. Our objectives were to resurvey these stands using the same sampling methods used by Dr. Davidson, thereby allowing us to evaluate forest changes over the last five decades. Additionally, we quantitatively sampled shrub and ground-cover strata, which were not surveyed in 1968 and 1969, to further characterize these forests.

Brule River Watershed Forest Background

During the late 19th century and early 20th century, most of the original timber of the Brule River watershed had been harvested (Wisconsin Department of Natural Resources 2015a). The pines (*Pinus resinosa*, and *P. strobus*) were harvested first for building projects throughout the Midwest. This initial harvest was thorough, removing all trees and leaving large woody debris piles behind. Once these piles dried out, they became a catalyst for catastrophic fires, which were commonplace for decades after the initial harvest. Many of these early fires burned hot and destroyed the fragile topsoil in some areas, restricting the ability of the land to support new forest (Wisconsin Department of Natural Resources 2016b). Some of the flat upland areas in the boreal forest and the pine barrens were further cleared for agricultural purposes. Most of the pine barrens farms were short-lived and were soon abandoned. In subsequent years, the barrens were extensively converted to pine plantations by public and private interests (Wisconsin Department of Natural Resources 2015a). In the 1920s the forest industry harvested the northern hardwoods, *Quercus* spp., *Acer* spp., *Tilia americana*, *Fraxinus americana*, and *Betula papyrifera*. This harvest continued sporadically through the 1930s and early 1940s (Wisconsin Department of Natural Resources 2015a).

The Brule River State Forest (BRSF) was officially declared a state forest in 1936. The idea for a state forest on the Bois Brule River (often referred to as the Brule River) first arose in 1907 when timber baron Frederick Weyerhauser gifted over 1,619 ha to the state of Wisconsin (Wisconsin Department of Natural Resources 2015a). The BRSF is mainly located in a narrow band of the watershed from glacial ridge to glacial ridge, stretching the entire length of the river, 71 km. The Brule River spillway (glacial ridges) was a main drainage outlet for glacial Lake Duluth, 10,000 ya and flowed from north to south carving the river channel we see today. As the land rebounded and lake levels lowered the river flow reversed its direction back to modern day Lake Superior (Clayton 1984).

The 2017 BRSF master plan mandated a shift towards timber production lands (27% to 58%) and away from protected natural lands. Annual harvests will remain the same, but greater disturbance will occur over time (Wisconsin Department of Natural Resources 2017). The BRSF comprises approximately 38% of the forested land in the watershed. The remaining 62% is either privately owned, part of the county forest, and /or a mixture of agricultural, residential development, rivers, lakes and wetlands. Significant areas within the BRSF with protected status include the steep sides of the Brule river valley and several state natural areas. These natural areas comprise 1,069 ha of *Thuja occidentalis* swamps in the headwaters (Figure 1), 264 ha of boreal forest approaching old growth status, 265 ha of open barrens, and a 9 ha small alkaline seepage lake with a sandy shore.

METHODS AND MATERIALS

Davidson created hand-drawn outlines on USGS topographic maps of the 54 forest stands surveyed in his study. Davidson's stands were rectangular and covered 27,600 m^2 with average dimen-

FIGURE 1. The lower reaches of the Bois Brule River at Stone's Bridge along a belt of old growth *Thuja occidentalis* swamp containing several populations of rare species. Photo by Paul Hlina.

sions of 240 m × 115 m. We georeferenced his stand boundaries with a digitizing routine in ArcMap 10.5, a geographical information system (GIS) mapping application. Using the digitized stand boundaries, we examined public forestry records from the Wisconsin Department of Natural Resources forest stand database (Wisconsin Department of Natural Resources 2016a) to evaluate the current forest community at each site. Forty-eight of Davidson's 54 forest stands (89%) were accessible for resurvey on both public and private lands. Davidson did not classify the forest stands into community types. Prior to field work and upon a cursory examination of the historical data, forest stands were classified based on the land cover data and, as defined by Wisconsin Department of Natural Resources (Epstein 2017). There are nine major forest communities in the watershed: boreal forest, northern dry forest, northern dry-mesic forest, northern hardwood forest, northern mesic hardwood forest, northern hardwood swamp, northern wet forest, northern wet-mesic forest and pine barrens. The northern hardwood forests were further separated by dominant tree species in each stand (aspen, oak-maple, or mixed). These forest types represent 58.3% of all the forests that were re-surveyed.

Davidson used the point-centered quarter sampling method developed by Cottam and Curtis (1949) to survey trees and saplings at each site, and we used the same method here. This method is one of the most frequently used distance methods employed to sample forest communities (Johnson et al. 2008). Cottam and Curtis (1956) evaluated several forestry sampling methods to quantify these forests and deemed the point-centered quarter method the best in terms of distance determinations and the amount of tree species data at each point. Bryant et.al. (2004) illustrated that the point-centered quarter method can result in biased density estimates when plant distribution deviates from random spatial patterns. We replicated the Davidson sampling design using the point-center quarter method. We used GIS to place one to five transects per stand, depending on the shape of the stand, with the criterion of a homogenous forest community. Transects were separated by at least 25 m. We distributed points along transects at 20 m intervals, and at each point the nearest tree and sapling in each of the four quarters was recorded. If no tree or sapling was present in a quarter within 12.2 m

FIGURE 2. Stephanie Glass (University of Wisconsin-Superior student) taking a dbh measurement in an old growth northern dry-mesic forest stand on the east side of the Bois Brule River on private land. Photo by Paul Hlina.

(40 ft.) of the survey point that quarter was marked as NONE. Trees are defined as individuals with stems measuring at least 10 cm diameter at breast height (dbh) while saplings were defined as individuals with stems between 2.5 cm (1 in) dbh and 10 cm dbh. as they were by Davidson in another vegetation study of the time period (Buell et. al 1966). The measurements were recorded in inches and later converted to centimeters, for all trees (Figure 2). Importance values per species were determined by calculating for relative frequency, relative density and relative dominance.

We also surveyed the groundcover (< 1 m) and shrub (ranging 1 m–3.65 m) strata in 48 forested stands using a modified method derived from the National Forest Inventory and Analysis (FIA) program developed by the U.S. Forest Service (Schulz et. al. 2009). Our modification of the FIA excluded importance values for trees and saplings, as this data was collected using the point-centered quadrat method described earlier. Each forest stand has four circular plots with a 7.32 m radius with the first identified by using the centroid of the 1968–69 stand surveys. The other three plots are located 36.58 m apart at 120°, 240° and 360° (Figure 3). For sampling of the groundcovers each plot contains three quadrats (1 m × 1 m) located at 4.57 m along each of three transects at 30°, 150° and 270° azimuths. A final modification is the addition of a circular microplot (2.07 m) east of the centroid for sampling the shrub stratum. Trees and saplings were included if they were presence in the quadrats or microplots (Figure 4).

We recorded the presence and estimated percentage cover to the nearest percentage of all species present in the quadrats and the microplot. Leaf litter and non-vegetated bare areas were recorded as percentage cover in the groundcover stratum. The shrub strata were only estimated in the microplot nested within each plot. All species, including dominant species were averaged between all stands of the same forest community type. Dominant species are those that exhibit higher frequency, density and cover values. One species list was created for each forest community by combining all species found in all the plots and microplots of that community and then removing any duplicate species.

Nomenclature follows Voss and Reznicek (2012), which includes most species found in Wiscon-

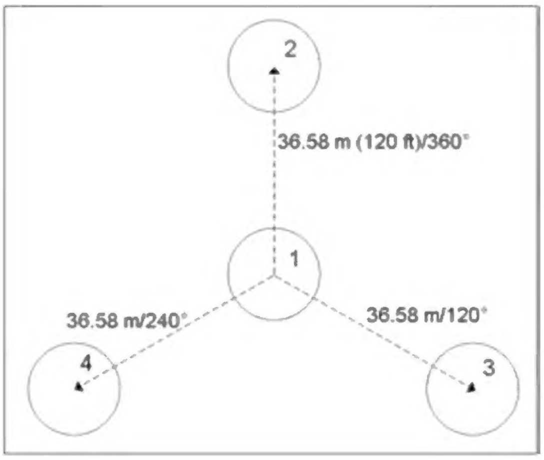

FIGURE 3. FIA plot layout. Each plot is composed of four circular plots 7.32 m in diameter; three of these are spaced 36.58 m, center to center, from a central subplot at azimuths of 120°, 240°, and 360°.

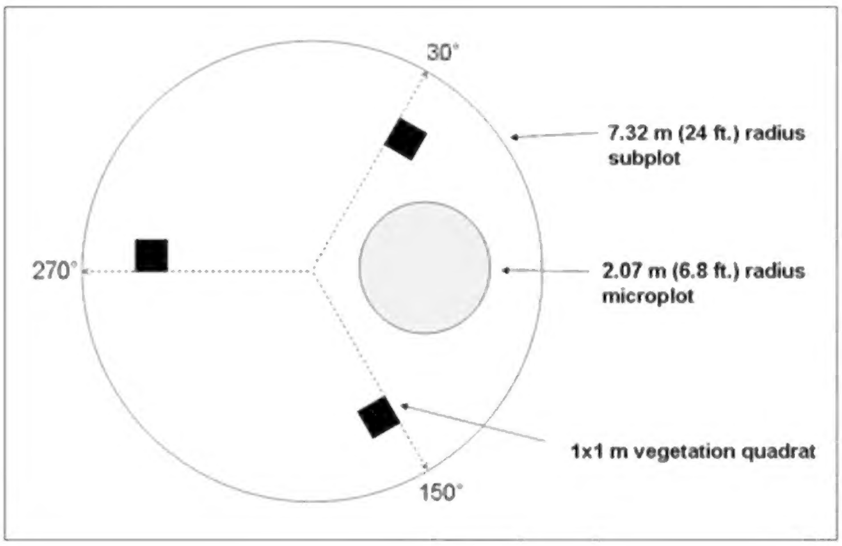

FIGURE 4. Standard FIA subplot diagram. Three quadrats are found along each transect line and quantitative data of cover values and species are recorded. A complete species list is compiled throughout for each subplot.

sin. For those species not found in Michigan Flora, Flora of North American Editorial Committee (1993+), and Judziewicz et al. (2014) were used. Difficult-to-identify plants were collected, tagged, and brought back to the herbarium for further identification.

Analysis

We provide a proportional representation of each tree and sapling species by calculating relative frequency, relative density, and relative dominance in the watershed forest for 1968 and 2016 (Figure 6). Relative frequency is the presence of each species over total number of quarters. Relative density is the total number of each species in all quarters divided by total quarters. Relative dominance is the relative density × basal area over the total basal area. These three values were summed to arrive at an importance value for each species, given as a percentage in Table 1.

We used the Bray-Curtis dissimilarity index (Bray and Curtis 1957) as a numerical measure of the ecological distance or dissimilarity. The Bray-Curtis formula compares forest community types at different times (1968 and 2016). The formula is expressed as follows:

$$BC_{ij} = 1 - (2C_{ij} / (S_i + S_j)),$$

where BC_{ij} is the Bray-Curtis dissimilarity index between sites i and j; C_{ij} is the sum of only the lesser counts for each species found in both sites; S_i is the total number of species counted on site i; and S_j is the total number of species counted on site j. The result of the calculation is a number between 0 and 1. The higher the value the more dissimilarity exists between the units compared. We compared trees to trees to measure forest composition changes over time. We further compared 1968 saplings to 2016 trees to measure re-generation of saplings to mature trees and finally we compared 2016 trees to 2016 saplings to measure potential regeneration for future forests.

A modified floristic quality assessment is used to provide an ecological condition assessment based on all species in the forest. This assessment was originally developed in the late 1970's in the Chicago region to identify protection-worthy lands with a simple, repeatable, quantitative method (Swink and Wilhelm 1979). They assigned to each species in the Chicago region a Coefficient of Conservatism (C), a number from 0 to 10. In the early 2000s, Wisconsin expert botanists convened and did the same for Wisconsin's vascular plants (Bernthal 2003). This list is now maintained by Wisconsin Department of Natural Resources (Wisconsin Department of Natural Resources 2016c). Species that are relatively tolerant of anthropogenic disturbance have low C-values, whereas species that are less tolerant of anthropogenic disturbance have high C-values (Spyreas 2019). We define tolerant species as those with C-values $\leq$ 5, and conservative species as those having C-values $\geq$ 6. Non-native species and some invasive native species are assigned a C-value of zero.

We calculated a weighted Coefficient of Conservatism (*wC*) (Bourdaghs 2012), which takes abundance into account, for each forest community type using the following formula:

$$wC = \Sigma\, pC.$$

The C-value of each species in the community is multiplied by its proportional abundance (p), and these values are then summed for all species in the community to provide a *wC* value for the community. The proportional abundance of a species is its weighted cover value divided by the total percentage cover for all species in the community. The *wC* value represents a baseline of condition for the community during the time of the survey.

RESULTS

Status and Change of Trees and Saplings

In selecting forest stands to survey, Davidson achieved a geographic distribution throughout the watershed as well as an equitable number of private versus public stands (Figure 5). Twenty-eight stands (58.3%) were represented as northern hardwood forests, which was further categorized as aspen dominated, oak–maple dominated, or mixed conifer. Four additional forest communities included pine barrens, northern wet-mesic, northern wet and northern hardwood swamps with only one or two stands surveyed. All other forest types had three or more representative stands. Average absolute density for all trees across all community types in 1968 was 131 trees/ha with an average basal area of 10.3 m^2/ha. In 2016, our surveys found an average absolute density of 98 trees/ha with an average basal area of 9.7 m^2/ha, which represents a substantially lower tree density but a similar basal area. The sapling data indicates an increase in earlier-successional forests than during the 1968–69 time period. Five stands (11%) have been clear-cut or partially cut in the last decade. Another six stands (13%) had larger ratios of saplings to trees, indicating a recently disturbed forest (e.g., harvesting, wind damage, development). Notable changes in tree and sapling data were found between the time periods in three species: *Betula papyrifera*, *Abies balsamea*, and *Acer rubrum*. Quantitative changes in trees and sapling of each tree species is discussed below. The importance values of these tree species are provided in Table 1.

Populus tremuloides and *P. grandidentata* comprised 30.2% of the forest

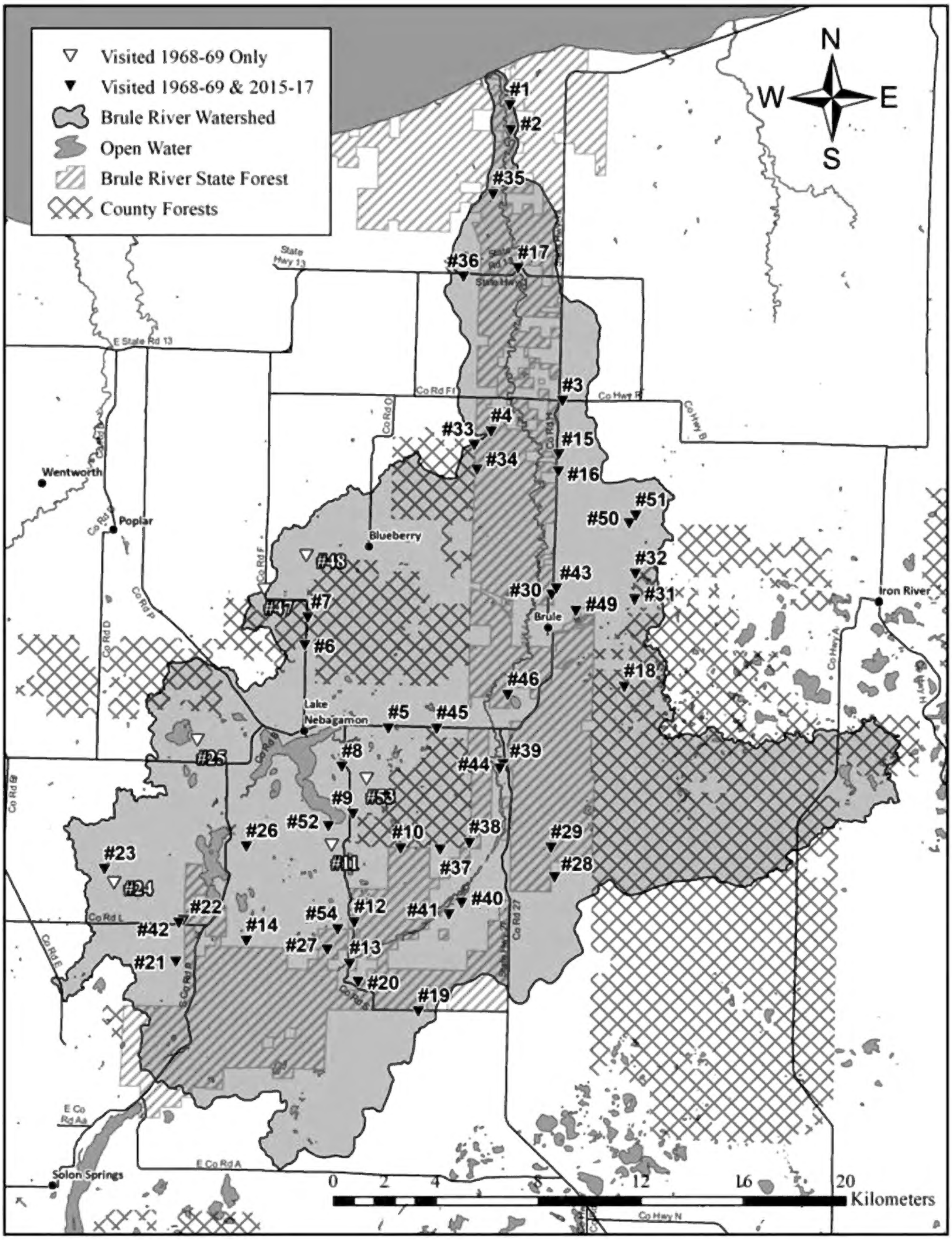

FIGURE 5. The locations of the 54 forest stands surveyed by Davidson and the 48 stands revisited in 2015 and 2016.

trees in 1968; today they have decreased to 21.1%. Saplings increased from 9.1% to 16.2%.

Betula papyrifera comprised 13.6% of the forest trees in 1968; recently they have decreased to 3.3%. Very few individuals of *Betula papyrifera* of any size were found. Larger individuals of *Betula papyrifera* were found only in older stands, and the relative density and relative dominance has dramatically decreased. The sapling data indicates that the relative density and relative dominance of *Betula papyrifera* saplings have decreased by 225%. As with trees, the percentage of saplings have decreased from 16.2% in 1968 to 6.3% today.

Abies balsamea comprised 5.5% of the forest trees in 1968 but has recently increased to 10.6%. Our sapling data indicates that it is germinating well across all community types and now has increased in relative density and relative dominance by 35%.

The relative density of *Picea glauca* trees has increased, while there has been a slight decrease in its relative dominance. The relative density and relative dominance of saplings have increased by 400% and 100%, respectively. Harvesting data indicates that selective cutting of larger trees has occurred in some of the boreal forest stands surveyed, potentially reducing spruce dominance (Wisconsin Department of Natural Resources 2016a).

Pinus strobus has increased in relative density by 100% and in relative dominance by 30%. Old growth pine trees cover the steep river valleys, and estimates based on landowner knowledge place these trees at 250–300 years old on two stands and 125–200 years on two other stands. The largest *Pinus strobus* trees

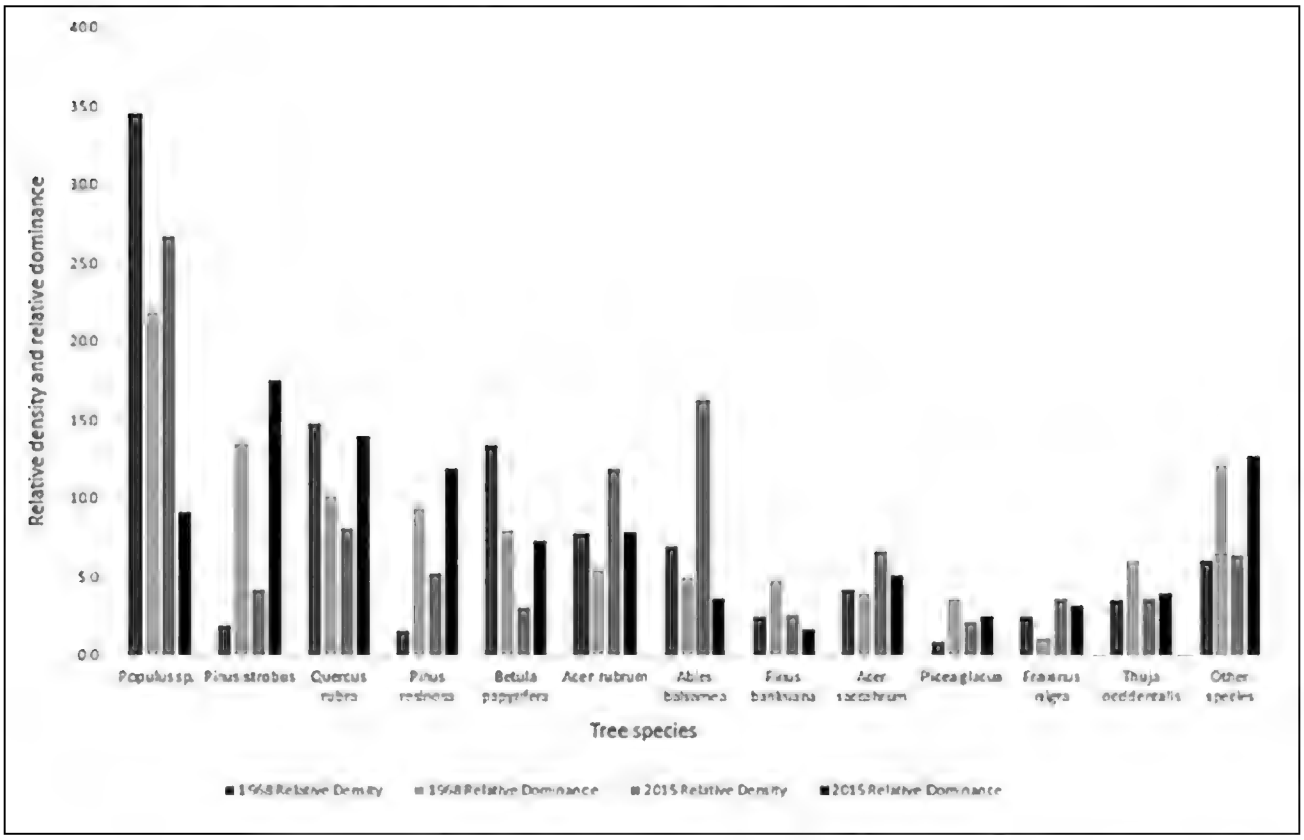

FIGURE 6. Relative density and relative dominance of forest trees in the Brule River watershed in 1968 and 2016. Tree species in the others category included species ranging from *Tsuga canadensis* to *Ulmus americana* and have a smaller influence in the forests.

TABLE 1. Importance values, expressed as a percentage, of common species in the watershed, calculated separately for trees and saplings. Because *Populus* saplings were difficult to identify to species, the entry for *Populus* sp. includes *P. tremuloides, P. grandidentata,* and *P. balsamifera.*

	Importance Values			
	Trees		Saplings	
Species	1968	2015	1968	2015
Abies balsamea	5.5	10.6	11.4	21.6
Acer rubrum	8.9	13.6	26.4	16.5
Acer saccharum	6.0	7.0	16.2	6.3
Betula alleghaniensis	0.7	0.7	0.1	0.5
Betula papyrifera	13.6	3.3	10.1	3.7
Fraxinus nigra	1.6	3.3	1.6	4.0
Pinus banksiana	4.3	3.0	2.6	7.7
Ostrya virginiana			2.6	7.7
Picea glauca	1.1	2.0	0.6	2.2
Pinus resinosa	3.0	7.5	0.2	1.7
Pinus strobus	2.8	6.4	0.7	1.1
Populus grandidentata	15.1	8.3		
Populus tremuloides	15.1	12.8		
Populus sp.			9.1	16.2
Prunus serotina			0.4	1.8
Quercus rubra	14.0	14.3	3.2	6.0
Rhamnus cathartica			0	0.1
Tilia americana	1.8	2.6		
Thuja occidentalis	1.6	0.7	0.5	0.1
Other	5.0	4.0	16.9	10.7

(>90 cm dbh) of the late 1960s exist only as snags today. The death of old trees and the absence of seedlings for regeneration will restrict the ability of these old growth forests on the Brule River watershed to be sustainable into the future. However, there are seedlings and saplings of *Pinus strobus* in the boreal forest communities, which may result in its further recovery in these forests.

Pinus banksiana was found primarily in pine plantations or as a small component of the northern dry and northern dry-mesic forest. Relative density has remained the same with a slight decrease in relative dominance.

Pinus resinosa is an important component of the old growth forest on northern dry and northern dry-mesic forest stands. In these old growth areas both relative density (300%) and relative dominance (25%) increased. Most of the increase in relative dominance can be attributed to an average increase of dbh in these sites (45 cm in 1968, 56 cm in 2016), in which the canopy trees are better represented by *Pinus resinosa* than *P. strobus.* The shade tolerant species, *Acer rubrum* and *Abies balsamea*, are abundant in the understory.

Acer rubrum trees comprised 8.9% of the forest in 1968; today they have increased to 13.6%. *Acer rubrum* has increased in presence and size. The relative density of *Acer rubrum* saplings has decreased from 26.4% to 16.5%, but its relative dominance has remained constant.

TABLE 2. Bray-Curtis dissimilarity index values for forest communities in the Brule River watershed, showing comparisons between trees (T) in 1968 and 2016, between saplings (S) in 1968 and trees in 2016, and between trees and saplings in 2016. The higher the values the more dissimilar the communities. The pine barrens, northern hardwood swamp, northern wet-mesic forest, and northern wet forest community types are poorly represented in the Davidson data and are therefore not analyzed under Bray-Curtis.

Forest Community Type	1968T_2016T	1968S_2016T	2016T_2016S
Boreal forest	.26	.31	.31
Northern dry-mesic (old growth)	.28	.45	.28
Northern hardwood–aspen	.36	.33	.37
Northern hardwood–oak/maple	.37	.42	.26
Northern hardwood–mixed conifer	.29	.31	.27
Northern mesic	.31	.37	.24

Quercus rubra comprised 14.0% of the forest trees in 1968 and has slightly increased to 14.3%. The percentage of saplings has increased from 3.2% to 6%.

Acer saccharum trees comprised 6.0% of individuals in 1968 and has increased to 7.0%. *Acer saccharum* also experienced an increase in relative density and relative dominance between the two surveys. Sapling numbers have declined from 16.2% to 6.3%.

Forest Community Composition and Change

Our findings with respect to these forests are consistent with those reported in earlier publications (Epstein et al 1999; O'Connor, 2016). Early successional forest remains the dominant forest type throughout the watershed, often consisting of *Populus* spp. and *Pinus* spp. There remain pockets of old growth forest with large diameter trees of *Thuja occidentalis*, *Pinus strobus, Pinus resinosa*, and *Picea glauca*, which indicates a larger and older forest that supports higher levels of species richness. Sapling numbers have increased with changes for individual species differing in relation to natural succession, harvesting, fire, and/or wind damage between the two time periods.

The Bray-Curtis dissimilarity index was used to depict differences in tree and sapling composition between the time periods (Bray and Curtis 1957). In comparing trees and saplings in the northern hardwoods forest community type between 1968 and 2016, there is a smaller difference in species composition than in that of the other forest communities, which suggests that the sapling layer is more similar in these northern hardwoods (Table 2). Eight to ten tree species rotate dominance at any one-time period across even-age and multi-age stands. Analysis of tree and sapling data showed a dramatic disappearance of *Betula papyrifera* across all northern hardwood forest community types, thereby widening the ecological distance between the two time periods. The most notable species with increased importance values were *Acer rubrum* and *Abies balsamea.* The remaining species in the northern hardwoods exhibited both rising and declining importance values equitably. The northern mesic forest tree composition has remained consistent between the two time periods with *Acer saccharum* remaining

dominate with *Betula allegheniensis, Tilia americana*, and *Acer rubrum* as common associates. Successional stage and stand location influence which species dominates in each stand. Boreal forest and northern dry-mesic forest have the smallest differences in species composition between the two time periods. In 60% of the northern dry-mesic stands, the largest living individuals of *Betula papyrifera* were recorded as a subcanopy tree in old growth forest. The comparison of saplings in 1968 to trees in 2016 indicates that many forest community types are widening their ecological distance, suggesting a greater change in species composition in the forest today than would be expected from the sapling data of 1968. The comparison of saplings to trees in 2016 in all forest community types depicts a future forest with a similar species composition, except in old growth forest. Sapling species composition in old growth forest suggests a departure from old growth pine to mixed conifer-hardwood forest (Table 2).

Old growth northern dry-mesic forest had the highest *wC* value of 5.2, while the northern hardwood–aspen had the lowest *wC* value at 3.9. The boreal forest and the northern hardwood–aspen had the highest average number of species richness at 71; however, the northern hardwood mixed conifer had the greatest species richness at 190. The northern hardwood–oak/maple forest had the highest percentage of non-native species at 16%, followed closely by the boreal forest, which had 14%. The lowest percentage of non-native species was recorded for the northern mesic forest at 5% and the northern dry-mesic forest at 7% (Table 3).

Groundcover and Shrub Strata by Forest Community Type

Boreal forest

The dominant groundcover species are *Eurybia macrophylla*, *Rubus pubescens*, *Rubus parviflorus* and *Cornus canadensis*; the first of which has a substantially greater abundance than the others. *Rubus parviflorus* is ranked third, as it was found on north and west facing slopes in only ten quadrats but is a sprawling vine-like shrub with large leaves often with high cover values. The shrub stratum is dominated by seedlings of *Abies balsamea* and mature *Alnus incana.* Other species of importance in this stratum are seedlings of *Fraxinus pennsylvanica* and *F. nigra.* Associated species include *Populus tremuloides*, *Amelanchier arborea*, *A. sanguinea*, and *Rubus parviflorus.*

The boreal forest is found north of the town of Brule to the mouth of the river. These forest stands exhibit an increase in species richness from the 1940s to present day as a result of increases in non-native plants from 5% in 1940s to 14% today. Native plants across all forest strata continue to dominate the floristic character of this forest. In some stands, conservative species remain strong: *Acer spicatum*, *Clintonia borealis*, *Dryopteris carthusiana*, *Dryopteris intermedia*, *Cynoglossum boreale*, and *Petasites frigidus* var. *frigidus*.

Northern dry-mesic forest

The dominant groundcover species are *Maianthemum canadense*, *Acer rubrum*, and *Cornus canadensis.* Subdominant species include *Abies balsamea*

TABLE 3. Several metrics for seven forest community types in the Brule River watershed. The northern wet, northern wet mesic, and northern hardwood swamp forest community types lacked a sufficient number of plots surveyed to conduct a meaningful analysis. Species richness is the number of species recorded in all plots in each community type and is the sum of the native and non-native species totals. Mean richness is the average number of species per 4 plots/1 stand. The weighted mean coefficient of conservatism (*wC*) is calculated for all species (native and non-native) and for only native species in each community type.

Forest Community Type	Number of plots	Number of quadrats	Number of mini-plots	Mean richness	Species richness	Species Totals: Native	Species Totals: Non-native (%)	*wC*: Native species	*wC*: All species
Boreal forest	16	48	16	71	134	118	16(14%)	5.2	5.1
Northern dry-mesic	16	48	16	57	113	105	8(7%)	5.4	5.2
Northern hardwoods–aspen dominated	36	108	36	71	172	153	19(11%)	4.1	3.9
Northern hardwoods–oak–maple	48	120	48	58	185	156	29(16%)	5.2	4.8
Northern hardwoods–mixed conifer	28	84	28	63	190	170	20(11%)	4.2	4.0
Northern mesic hardwoods	24	72	24	66	159	151	8(5%)	5.2	5.0
Pine barrens	8	24	8	63	116	105	11(9%)	4.6	4.3

and *Oryzopsis asperifolia*. This forest type is rare in the watershed, and most stands are in private landholdings. The shrub stratum is dominated by seedlings of *Abies balsamea* and *Acer rubrum*, but *Corylus cornuta*, *C. americana*, and *Ostrya virginiana* have a significant role in this stratum. Associated species include *Pteridium aquilinum*, *Quercus rubra*, and, in one stand, *Pinus strobus*. *Pinus resinosa* has the highest importance value, and *P. strobus*, *Betula papyrifera*, and *Abies balsamea* are associated species.

The northern dry-mesic forest represents climax successional conditions and exhibit stability. Species are equally made up of tolerant species (41%) and conservative species (42%). Some of the conservative species are: *Dirca palustris*, *Pyrola americana*, *Moneses uniflora*, *Lonicera villosa*, and *Linnaea borealis*.

Northern hardwood forest

We have divided the northern hardwood forest into three categories: aspen dominated, oak/maple dominated, and mixed conifer dominated. These transi-

tional forests fluctuate between one another over a relatively short time period (40–80 years).

Aspen dominated

The dominant species in the groundcover stratum are *Pteridium aquilinum*, *Eurybia macrophylla*, and *Rubus pubescens*. Interestingly, *Diervilla lonicera*, dominant in Thomson's 1940's surveys, was rarely encountered in our surveys. The shrub stratum is dominated by *Ilex verticillata*, *Fraxinus pensylvanica*, and *Viburnum rafinesquianum*. Other species of importance in this stratum are seedlings of *Populus grandidentata*, *Quercus rubra*, and *Acer rubrum.* Associated species include *Amelanchier arborea*, *Ostrya virginiana*, *Corylus americana*, *C. cornuta*, *Prunus pensylvanica*, and *P. serotina.*

Mixed conifer

The dominant species in the groundcover stratum are *Pteridium aquilinum*, *Eurybia macrophylla*, *Carex pensylvanica*, and *Acer rubrum* seedlings. These stands were all early to mid-successional forest. The shrub stratum is dominated by seedlings of *Acer rubrum*, *Populus tremuloides*, and *P. grandidentata* and mature *Ostrya virginiana*, *Corylus americana*, and *C. cornuta.* Surprisingly, *Quercus rubra* and *Acer saccharum* were of less importance in the shrub stratum. Associated species include *Betula papyrifera*, *Pinus strobus*, *Prunus serotina*, *and Dirca palustris.*

Oak/maple dominated

The dominant species in the groundcover stratum are *Eurybia macrophylla*, *Maianthemum canadense*, *Carex pensylvanica*, *Pteridium aquilinum*, and *Acer rubrum* seedlings. Dominance in the groundcover stratum fluctuates between these five species in all the hardwoods as these communities are all second growth forest spanning early-, mid-, and late-successional stage forest. The shrub stratum is dominated by seedlings of *Abies balsamea*, *Populus grandidentata* and *Acer rubrum* and mature *Corylus americana* and *C. cornuta.* The species richness as in other hardwood forest, is high with the following associates: *Picea glauca*, *Rubus alleghaniensis*, *Alnus incana*, *Viburnum lentago*, *Betula papyrifera*, *Populus tremuloides*, *Quercus rubra*, *Acer saccharum*, *Pteridium aquilinum*, *Pinus strobus*, *Prunus pensylvanica*, *P. serotina*, *Tilia americana*, *and Carpinus caroliniana.* Species richness is 185 species, and these seven-species represent 31.2% of the groundcover stratum in the forest. Tolerant species (57%) have a 2:1 ratio over conservative species (28%).

In these northern hardwood forests, species richness is 185 species, and the seven dominant species represent 31.2% in the groundcover stratum of these forests. Tolerant species (57%) have a 2:1 ratio over conservative species (28%).

Northern mesic hardwoods

The dominant groundcover species are *Rubus pubescens* and tree seedlings of *Acer saccharum*, *A. rubrum*, and *Fraxinus pennsylvanica* followed by *Maianthemum canadense* and *Trientalis borealis* which had lower frequency and cover

values. The shrub stratum is dominated by seedlings of *Acer saccharum*, *Acer rubrum*, and *Abies balsamea,* with *Corylus cornuta* and *Ostrya virginiana*. Associated species include *Acer spicatum*, *Fraxinus americana*, *Betula papyrifera*, and *Carpinus caroliniana.*

The northern mesic forest is comprised of *Acer saccharum*, *Betula alleghaniensis*, *Tilia americana*, and *Tsuga canadensis*. Northern mesic forest represents only 2% of the forest in the watershed and are the most western forest of its type in Wisconsin. The forest type is best represented in the Brule River watershed at the Sugar Camp Hill stand area, north of the town of Brule. One *Tsuga canadensis* stand supported the largest patch (approximately 2m × 7m) of *Adiantum pedatum* in the watershed at the bottom of a ravine. Two other observations of this species were made, but only of individual plants. Species richness is high, and conservative species (52%) have a slightly higher representation than tolerant species (48%). Conservative species are: *Carex disperma*, *Woodsia ilvensis*, *Chrysosplenium americanum*, *Panax trifolius*, *Dirca palustris*, and *Carex backii* (a state special concern species).

Pine barrens

One site had been clear cut in the recent past resulting in an open barrens-like community. Groundcover and shrub data from this site were added to the analysis. The dominant groundcover species are *Pteridium aquilinum*, *Corylus americana*, *Vaccinium angustifolium*, *Quercus macrocarpa*, and *Carex pensylvanica*. The shrub stratum is dominated by *Corylus americana*, *Quercus ellipsoidalis*, *Quercus macrocarpa*, and *Pinus banksiana*. Associated species with lower importance values include *Amelanchier spicata*, *Prunus pensylvanica*, and *Pinus strobus*. Non-native species have been well represented in the floral record for the pine barrens community. Thomson (1944) observed that 17% of the flora was non-native, while our surveys found 13.4%.

Northern hardwood swamp

One northern hardwood swamp stand was revisited, representing only 2% of the forest surveyed in 2015. With only one sample in the survey, there are no trends we can point to with any level of confidence. There were only four plots for groundcover species and the data was too sparse to analyze. Furthermore, species composition and total species richness differed between the two surveys, as geo-referencing was less accurate because of the large expanse of this forested wetland mosaic.

Northern wet forest

One northern wet forest was re-visited, representing 2% of the forest surveyed. Within the Brule river watershed, this community is relatively rare. Stands are small and, when away from the river corridor, often isolated. These stands are dominated by either *Picea mariana* or *Larix laricina* growing in a thick layer of sphagnum moss and ericaceous shrubs. Davidson had visited only one stand, and we are unable to identify trends in this community. Analysis was not conducted as only one stand/four plots were surveyed.

Northern wet-mesic forest

One *Thuja occidentalis* swamp was revisited representing 2% of the forest surveyed in 2015. Analysis was not conducted as only four plots were surveyed.

DISCUSSION

As is noted in the results section, significant changes are evident in individual tree species, as well as forest communities. *Betula papyrifera* is declining rapidly everywhere we surveyed. In our observations only mature trees and young saplings are present, with most middle-aged trees fallen or upright dead snags. Since 1983, the mortality rate of *Betula papyrifera* has exceeded its annual growth in Wisconsin (Wisconsin Department of Natural Resources 2016b). As climate change models illustrate (Scheller and Mladenoff 2005), it is predicted that by the end of the 21st century, *Betula papyrifera* may become extirpated from northern Wisconsin. The death of old pines *(Pinus resinosa* and *P. strobus*) and cedars (*Thuja occidentalis*) and the absence of seedlings for regeneration will restrict the ability of these old growth forests on the Brule River watershed to be sustainable into the future. However, there are some seedlings and saplings of *Pinus strobus* in the boreal forest communities, which may result in further recovery in these forests.

Two trees that are having a greater influence across several forest community types are *Acer rubrum* and *Abies balsamea.* These two species threaten the viability of the old growth northern dry-mesic forest, as well as other northern forest communities. Fire, at frequent intervals, remains evident on *Pinus resinosa* trunks and was the primary disturbance responsible for regenerating these stands (Meunier et. al. 2019). Today, these old growth stands represent less than 1% of all forest in the watershed.

Though these stands are climax communities, they are not without threats. Without ground fires to reduce the groundcover and shrub layers (e.g., *Acer rubrum* and *Abies balsamea* saplings) *Pinus resinosa and P. strobus* recruitment will remain low (Meunier et. al. 2019). A large storm in the summer of 2016 created several gaps in the forest canopy. Active pine plantings in naturally occurring openings today and in the future may benefit the old growth forest. Absent of natural or human re-planting activities, these gaps provide invasive non-native plants an opportunity to get a stronger foothold. Several small scattered populations of a few non-native species are already present (e.g., *Hieracium aurantiacum* and *Ranunculus acris*), an indicator of earlier disturbances.

By the 1940's logging activities greatly expanded on the narrowing boreal forest at the mouth of the watershed. These activities contributed to further fragmentation of the forest, along with new roads, cleared areas for development, and agricultural conversion. These disturbances serve as a conduit for non-native plants to expand their presence adjacent to and in the forest. Instead of tree seedlings germinating in gaps from natural causes, we now find opportunistic wind-pollinated non-native species out-competing the native species.

The 2003 Brule River State Forest master plan and environmental impact

statement outlined a 100-year conservation plan to restore the boreal forest by reducing the amount of *Populus tremuloides* density and dominance, while increasing *Pinus strobus, Picea glauca* and *Betula papyrifera* north of the Town of Brule to the mouth of the river (Van Horn et al. 2003). Data from the boreal forest depicts a forest in recovery from the initial harvest in the 1880's, with later successional to mature old growth forest present in some stands. Analyzing our data from the boreal forest stands indicates that since 2003, the boreal forest has higher tree importance values for *Abies balsamea, Picea glauca* and higher sapling importance values for *Pinus strobus,* but a declining presence of *Betula papyrifera* as discussed earlier. This report illustrates that the forest communities are multi-aged with high biodiversity of tree and sapling species, sustaining the plant and animal species that are dependent on these communities, as well as the human community.

The northern mesic forest communities are expansive in northeastern and north central Wisconsin but are rare in the watershed. The Sugar Camp Hill stand is the best example of this forest community type. It is managed as a shelter wood forest by the Brule River State Forest and was last harvested in 1933 (Wisconsin Department of Natural Resources 2016a). Between now and the next harvest in 2033, the forest will be thinned to allow new seedling to grow and thrive. At that time, the canopy of older trees will be removed, and a younger forest will then stand in its place. The stands near Lake Minnesuing consist of *Tsuga canadensis*, a frequent associate in the northern mesic forest. Davidson et al. (1973) reported *Tsuga canadensis* in these stands as the westernmost record for this species in Wisconsin at that time. Subsequent reports (e.g., Fryer 2018) now extend the range of this species into northeastern Minnesota. Future harvesting activities should strive to protect and sustain these rare stands in the watershed representing the westernmost northern mesic forest in the upper Midwest.

Northern hardwood swamp is lowland forest dominated by *Fraxinus nigra* (Figure 7). In the Davidson data there was only one stand represented, and trees were alive and healthy. However, today, northern hardwood swamp is threatened by a non-native insect pest, the emerald ash borer (*Agrilus planipennis*), which was discovered in 2014 in our region, 35 miles to the west in Superior, Wisconsin. In the summer of 2016, Schulz (personal communication), stated that *Agrilus planipennis* had not been found in the watershed. Our data along with other studies suggest that *Acer rubrum*, *Abies balsamea*, and *Alnus incana* may be the best adapted species to take advantage of the demise of the northern hardwood swamp (United States Forest Service 2014, Chaffin 2019).

More than 2,630 ha spanning the upper reaches of the watershed consists of the northern wet-mesic forest. The conifer swamp stands of the upper Brule River are generally mature, with some stands in or approaching old-growth condition. The forest understory is floristically rich, especially in orchids and sedges. The northern wet mesic forest is dominated by *Thuja occidentalis* with *Abies balsamea*, *Picea mariana*, *Fraxinus nigra*, and *Larix laricina* being common associates. Davidson recorded one stand in this forestry community type. This stand is an old growth forest dating back to 1838. Deer herbivory is a major problem affecting forest regeneration in these important wet-mesic forest on the Brule River. *Thuja occidentalis* seedlings are rare, and reproductive success has

FIGURE 7. A northern hardwood swamp forest of *Fraxinus nigra* on a perched ledge about 9 m above the Bois Brule River. These unique forests were created in a cut-off ox-bow meander of an earlier period of the river's history. These lowland forests remain free of the emerald ash borer, but are likely to be threatened in future years, as the pest has been found to the west in Superior, Wisconsin. Photo by Paul Hlina.

been low. These unique forest stands at the headwater areas of the Brule River have been recognized for their significance for decades (Fassett 1944, Thomson 1945). In 1945, the area was purchased by the Wisconsin Conservation Commission following recommendations by Thomson (1945) to halt all harvesting activity here. The same area received further protective status in the 1980s, and it was designated as a State Natural Area in 2003.

Northern dry forest has declined greatly due to post-EuroAmerican settlement harvesting and the replacement of these forest with pine plantations over the past century. These communities are fire dependent for seed release and growth and do not exist as pure stands today.

Pine barrens were once widespread throughout northwestern Wisconsin covering 9.3 million ha. Today, only two percent remain in heavily managed and protected areas (United States Forest Service 2001). Pine barrens is considered an endangered community type in Wisconsin (Wisconsin Department of Natural Resources 2015b). Vast hectares of the pine barrens landscape were converted to *Pinus resinosa* and *P. banksiana* plantations by both private and public interests. During this time and continuing today, many pioneer species, especially non-na-

tive species, occur in the sandy soils of the pine barrens due to frequent disturbances past and present, such as fires, logging, road building, agriculture, and harvesting and planting of tree plantations. Prior to EuroAmerican settlement, pine barrens was characterized by scattered *Pinus banksiana* or less commonly *P. resinosa* sometimes mixed with *Quercus ellipsoidalis* and *Quercus macrocarpa* (Radeloff et al. 2000). The scattered trees or groves are interspersed with openings in which shrubs, such as *Corylus americana*, and grass dominated prairies are the common cover types. These species benefit from periodic episodes of fire in creating and sustaining this mosaic of forest, openings, and prairies (Radeloff et. al. 1999). The best example in the watershed of an early successional pine barrens community is Mott's Ravine State Natural Area, designated in 2003, which is managed through prescribed fire treatments and shrub and tree removal. Examples of high quality pine barrens are also found nearby at Crex Meadows State Wildlife Area (Burnett County), Namekagon Barrens (Burnett County), Solon Springs Sharp-tail Barrens State Natural Area (Douglas County), and the Moquah Barrens (Bayfield County) (Wisconsin Department of Natural Resources 2015b). One of the most notable finds in the pine barrens was more than 200 stems of the threatened *Asclepias ovalifolia* (dwarf milkweed) at the outer edge of a 6-year old pine plantation. This is one of the most northern locations in Wisconsin for this species, which is more frequent in the southern prairies of the state. It appears that these plants and seeds remained dormant during the period prior to harvesting. Once the canopy was removed, these plants were able to rebound, but will likely disappear again as the young forest shades them out in the years to come.

Northern hardwood communities have seen the greatest disturbance in the past century, and some are second and third growth stands. In our re-survey of these three types of northern hardwood forest we found dominant species composition of only seven species: *Pteridium aquilinum*, *Eurybia macrophylla*, *Maianthemum canadense*, *Carex pensylvanica*, *Rubus pubescens*, *Vaccinium angustifolium*, and *Acer rubrum*. Rooney et al. (2004), conducting a re-survey of Brown and Curtis (1952) northern forest stands in Wisconsin, found that the understory diversity had become biotically impoverished. Rooney et al. (2004) note that species composition was becoming homogenized and that tolerant and non-native species were on the rise, threatening the ecological integrity of the forest. The baseline data represented in these hardwoods indicates a similar response. Future research projects could focus on one or more of the following potential threats. Are frequent disturbances having a negative or positive effect on the species richness of the northern hardwoods? Are we seeing the beginning stages of biotic impoverishment in the Brule River watershed? Are animal-dispersed and animal-pollinated species showing a decline, while wind dispersed species are rising? Are deer populations causing a shift in the floral composition? Are earthworm invasions having an impact on the duff or humus layer of the forest? Are climate resistant species increasing, decreasing, or staying the same?

CONCLUSION

The Bois Brule River flows through some of the most diverse habitats found anywhere in the state of Wisconsin. In 2015 and 2016, our survey teams were able to collect and analyze forest strata data from 48 of Davidson's 54 original forest stands from 1968 and 1969. A major finding here is that *Betula papyrifera* has declined throughout all the forest types of the region over the last 50 years. Our data confirm the continuing trend of the steep decline of *Betula papyrifera* statewide (Wisconsin Department of Natural Resources 2016b). A second group of tree species of concern in the watershed are *Fraxinus* spp. These trees are seriously threatened by the accidental introduction of *Agrilus planipennis* in shipping crates from Asia (Emerald Ash Borer Network 2015). Though not present in the stands we surveyed, *Agrilus planipennis* is creeping closer to the Brule River watershed, as indicated by the discovery of the pest 35 miles to the west in Superior, Wisconsin in 2013. What will replace these species? From our data, we can postulate that *Acer rubrum* and *Abies balsamea* are likely to be the future forest benefactors (United States Forest Service 2014; Chaffin 2019). The densities of these two species continue to be strong across several forest community types and has increased in importance in others that are adjacent to northern hardwood swamp. Both species have a high tolerance of shade, moisture, and soil conditions, which provides an advantage for these trees over other species.

In the Davidson data, we found a low number of stands in some forest community types. This factor, along with the lack of access to some privately held stands, restricted our ability to provide quantitative analysis of northern hardwood swamp, northern dry forest, northern wet-mesic forest and northern wet forest. In 1968 and 1969, Davidson identified five old growth forest stands (numbers 13, 39, 40, 41, and 44 in Figure 5). These virgin forests remain today. There are also stands (4 and 35 in Figure 5) that will soon achieve old growth status in the boreal forest region of the watershed.

Over the years, a balance has been successfully achieved between the multiple uses of this dynamic landscape (e.g., timber production, sensitive area protection, river and recreation, ecological health, and residential development), and the forests of the watershed are in good to fair condition. Non-native plants are ubiquitous across almost all community types, but in most communities at a low abundance and a high frequency. Still, other threats today and into the future challenge maintaining the balance, such as the expansion of non-native plants, insect infestations, forest fragmentation by roads and development, climate change (United States Forest Service 2014; Chaffin 2019), deer herbivory, catastrophic extreme climate events (e.g., wind throw and flooding), fire or lack of fire (Radeloff et. al. 1999; Meunier et. al. 2019) and potential increases in overharvesting for quicker financial returns (Rooney et al. 2004; Harper et al. 2005; Scheller and Mlandoff 2005; Stueve et al. 2011; Rooney et al. 2015). Informed land managers, community decision-makers, citizen conservation groups, and others will need to work in partnership to develop and implement strategies of sustainable practices that will guarantee a healthy and thriving forest for future

generations. Future studies should evaluate whether the delicate balance between ecological health and human impact has been successfully maintained.

ACKNOWLEDGMENTS

See the Acknowledgments section in Hlina (2020), which serves as Acknowledgments for both that article and this one.

LITERATURE CITED

Bernthal, T. W. (2003). Development of a floristic quality assessment methodology for Wisconsin. Wisconsin Department of Natural Resources, Madison.

Bourdaghs, M. (2012). Development of a rapid floristic quality assessment. Document number: wq-bwm2-02a, Minnesota Pollution Control Agency, St. Paul. (Available online at https://www.pca.state.mn.us/sites/default/files/wq-bwm2-02a.pdf).

Bray, J. R., and J. T Curtis (1957). An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349.

Brown, R. T., and J. T. Curtis (1952). The upland conifer-hardwood forests of northern Wisconsin. Ecological Monographs 22: 217–234.

Bryant, D. M., M. J. Ducey, J. C. Innes, T. D. Lee, R. T. Eckert, and D. J. Zarin (2004). Forest community analysis and the point-centered quarter method. Plant Ecology 175: 193–203.

Buell, M. F., A. N. Langford, D. W. Davidson, and L. F. Ohmann (1966). The upland forest continuum in northern New Jersey. Ecology 47(3): 416–432.

Chaffin, D. (2019). Climate change and future forests of the Boundary Waters Canoe Area Wilderness: An assessment of temperature tree abundance, earthworm invasion and understory regeneration trends. PhD. Dissertation for University of Minnesota, Minneapolis.

Clayton, Lee (1984). Pleistocene geology of the Superior region, Wisconsin. Information Bulletin no.46. Wisconsin Geological and Natural History Survey, Madison.

Cottam, G., and J. T. Curtis (1949). A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology 30: 101–104.

Cottam, G., and J. T. Curtis (1956). The use of distance measures in phytosociological sampling. Ecology 37**:** 451–460.

Davidson, D. W., R. A. Ahlberg, R. G. Koch, and D. J. Lahti (1973). A westward extension of hemlock in Wisconsin. The Michigan Botanist 12: 209–211.

Emerald Ash Borer Information Network. (2015). USDA Forest Service and Michigan State University. Available at http://www.emeraldashborer.info/ (Accessed April 9, 2016).

Epstein, E. E. (2017). Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 in: The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management. Wisconsin Department of Natural Resources, PUBSS-1131H 2017, Madison.

Epstein, E., W. Smith, J. Dubberpuhl, and A. Galvin. (1999). Biotic inventory and analysis of the Brule River State Forest. Wisconsin Natural Heritage Inventory Program. Madison.

Fassett, N. C. (1944). Vegetation of the Brule Basin, Past and Present Brule River Survey Report No.4 Transactions of the Wisconsin Academy of Sciences, Arts and Letters 35: 33–56.

Flora of North America Editorial Committee, eds. (1993+). Flora of North America North of Mexico.20+ vols. Oxford Univerity Press, New York, N.Y.

Fryer, Janet L., 2018. Tree species distribution range maps from Little's “Atlas of United States trees” series. Available at https://www.fs.fed.us/database/feis/pdfs/Little/aa_SupportingFiles/LittleMaps.html.

Harper, K. A., S. E. MacDonald, P.J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Skirchen, et. al. (2005). Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology 19: 768–782.

Hlina, P. S., R. J. Schwarting, M. A. Feist, and D. S. Anderson. (2018). Analysis of the vegetative cover of the Brule River Watershed revisited: 1852–2017. Technical Report 2018-3, Lake Superior Research Institute, University of Wisconsin, Superior.

Hlina, P. S., M. A. E. Feist, D. S. Anderson, P. B. Marcum, R. J. Schwarting, and N. P. Danz. (2020). Analyzing vegetative cover of the Bois Brule River watershed re-visited in northwestern Wisconsin, Part II: Vegetation and land cover changes (1852 to 2017). The Great Lakes Botanist 59: 24–96.

Johnson, S. E., E. L. Mudrak, E. A. Beever, S. Sanders, and D. M. Waller (2008). Comparing power among three sampling methods for monitoring forest vegetation. Canadian Journal of Forest Research 38**:** 143–156.

Judziewicz, E. J., R. W. Freckmann, L. G. Clark, and M. R. Black. (2014). Field Guide to Wisconsin Grasses. The University of Wisconsin Press, Madison.

Kronenfeld B.J. and Y.C. Wang (2007). Accounting for surveyor inconsistency and bias in estimation of tree density from presettlement land survey records. Canadian Journal of Forest Research 37: 2365–2379.

Meunier, J., N. S. Holoubek, and M. Sebasky (2019). Fire regime characteristics in relation to physiography at local and landscape scales in Lake States pine forests. Forest Ecology and Management 454: 117651.

O'Connor, R. (2016). Biotic inventory report for the Brule River State Forest: An updated inventory and analysis of rare plants and animals and high-quality natural communities in support of a Master Plan update. PUB-NH-856 2016 Wisconsin's Natural Heritage Inventory Program, Madison.

Radeloff, V.C., D.J. Mladenoff, H.S. He, M.S. Boyce (1999). Forest landscape change in the northwestern Wisconsin Pine Barrens from pre-European settlement to the present. Canadian Journal of Forest Research 29: 1649–1659.

Radeloff, V. C., D. J. Mladenoff, and M. S. Boyce (2000). A historical perspective and future outlook on landscape scale restoration in the Northwest Wisconsin Pine Barrens. Restoration Ecology 8: 119–126.

Rooney, T. P., S. M. Wiegmann, D. A. Rogers, and D. M. Waller (2004). Biotic impoverishment and homogenization in unfragmented forest understory communities. Conservation Biology 18: 787–798.

Rooney, T. P., R. Buttenschon, P. Madsen, C. Olesen, A. A. Royo, and S. L. Stout. (2015). Integrating ungulate herbivory into forest landscape restoration. Pp. 69–84 in Restoration of boreal and temperate forests. Second Edition, J. A. Stanturf, editor. CRC Press, Boca Raton, Florida.

Sanders, S., S. E. Johnson, and D. M. Waller. (2008). Vegetation monitoring protocol: Great Lakes inventory & monitoring network. Natural Resource Report NPS/GLKN/NRR—2008/056. National Park Service, Fort Collins, Colorado.

Scheller, R. M., and D. J. Mladenoff. (2005). A spatially interactive simulation of climate change, harvesting, wind and tree species migration and projected changes to forest composition and biomass in northern Wisconsin USA. Global Change Biology 11: 307–321.

Schulte, L. A., and D. J. Mladenoff. (2001). The original US public land survey records: Their use and limitations in reconstructing presettlement vegetation. Journal of Forestry 99: 5–10.

Schulte, L. A., D. J. Mladenoff, and E. V. Nordheim. (2002). Quantitative classification of a historic northern Wisconsin (U.S.A.) landscape: Mapping forests at regional scales. Canadian Journal of Forest Research 32: 1616–1638.

Schulz, B. K., W. A. Bechtold, and S. A. Zarnoch. (2009). Sampling and estimation procedures for the vegetation diversity and structure indicator. General Technical Report PNW-GTR-781. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Spyreas, G. (2019). Floristic quality assessment: a critique, a defense, and a primer. Ecosphere 10(8): e02825.10.1002/ecs2.2825.

Stueve, K. M., C. H. Perry, M. D. Nelson, S. P. Healey, A. D. Hill, G. G. Moisen, W. B. Cohen et. al. (2011). Ecological importance of intermediate windstorms rivals large, infrequent disturbances in the northern Great Lakes. Ecosphere 2**:** 1–21.

Swink, F., and G. Wilhelm. (1979). A method for environmental assessment of open land. Pp 850–861 in Plants of the Chicago region. The Morton Arboretum, Lisle, Illinois.

Thomson, J. W., Jr. (1944). A survey of the larger aquatic plants and bank flora of the Brule River. Brule River Survey: Paper No. 5 Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 35: 57–76.

Thomson, J. W., Jr. (1945). An analysis of the vegetative cover of the Brule River (Wisconsin) watershed. Brule River Survey Report No. 8. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 37: 305–323.

United States Forest Service (2001). Purpose and need for action and proposed actions on the Sunken Moose Project, Washburn District, Chequamegon-Nicolet National Forest, Bayfield County, Wisconsin. Available at https://www.federalregister.gov/documents/2001/04/24/01-10059/sunken-moose-project-chequamegonnicolet-national-forest-bayfield-county-wisconsin (Accessed May 23, 2020).

United States Forest Service (2005). Forest inventory and analysis national core field guide version 3.0. United States Department of Agriculture, Washington, D.C.

United States Forest Service. (2014). Forest ecosystem vulnerability assessment and synthesis for northern Wisconsin and western Upper Michigan: A report from the Northwoods Climate Change Response Framework Project. Gen. Tech. Rep. NRS-136. Newtown Square, Pennsylvania. U.S. Department of Agriculture, Forest Service, Northern Research Station. Available at https://www.nrs.fs.fed.us/pubs/46393 (Accessed May 24, 2020).

Van Horn, K., K. Brokaw, and S. Petersen (2003). Brule River State Forest master plan and environmental impact statement. Wisconsin Department of Natural Resources. Publication PUB-FR-225.

Voss, E. G., and A. A. Reznicek. (2012). Field manual of Michigan flora, The University of Michigan Press, Ann Arbor.

Wisconsin Department of Natural Resources (2015a). Brule River State Forest, Publication PUB-FR-158 2015.

Wisconsin Department of Natural Resources (2015b). Wisconsin Natural Communities Endangered Resources. Available at https://dnr.wi.gov/topic/EndangeredResources/Communities.asp (Accessed April 9, 2016).

Wisconsin Department of Natural Resources (2016a). Wisconsin forest inventory and reporting system. Brule River State Forest. Available at https://dnrxwisconsingov/wisfirs/external/wisfirsaspx (Accessed April 9, 2016).

Wisconsin Department of Natural Resources (2016b). Wisconsin State Forests. Available at https://dnr.wi.gov/topic/StateForests/ (Accessed April 9, 2016).

Wisconsin Department of Natural Resources (2016c). Wisconsin wetlands and tools for assessment. Available at https://dnr.wi.gov/topic/wetlands/methods.html (Accessed April 9, 2016).

Wisconsin Department of Natural Resources (2017). Brule River State Forest Master Plan. Available at https://dnr.wi.gov/files/pdf/pubs/fr/FR0225.pdf (Accessed December 11, 2018).

ANALYZING VEGETATIVE COVER OF THE BOIS BRULE RIVER WATERSHED RE-VISITED IN NORTHWESTERN WISCONSIN, PART II: VEGETATION AND LAND COVER CHANGES (1852 TO 2017)*

Paul S. Hlina[1,†], Mary Ann E. Feist[2], Derek S. Anderson[1], Paul B. Marcum[3], Reed J. Schwarting[1], Nicholas P. Danz[1]

[1]Lake Superior Research Institute, University of Wisconsin–Superior
Barstow Hall 4 Belknap and Catlin Ave
P.O. Box 2000, Superior, WI 54880

[2]Wisconsin State Herbarium, University of Wisconsin-Madison
Department of Botany, Birge Hall
430 Lincoln Drive, Madison, WI 53706

[3]Illinois Natural History Survey, Prairie Research Institute
University of Illinois at Urbana-Champaign
1816 South Oak Street, Champaign, IL 61820

ABSTRACT

The vascular plants of the Bois Brule River watershed are listed, and over 160 years of change in plant communities observed is described. The watershed covers approximately 51,300 ha in northwestern Wisconsin, primarily in Douglas County with a short arm extending eastward into Bayfield County. The Bois Brule River travels southwest to the northeast 71 km from its headwaters and drains into Lake Superior. The diverse landscape supports boreal forest, northern mesic forest, northern wet-mesic forest, pine barrens, and other forested and non-forested communities. Five generalized changes in the watershed were noted: (i) the pine barrens community declined by more than 95%, (ii) the northern wet-mesic forest (dominated by *Thuja occidentalis*) immediately surrounding the river has been reduced to a narrow band, (iii) the large complex of conifer wetlands is greatly reduced, (iv) northern hardwood swamp (dominated by *Fraxinus nigra*), *Alnus incana* thickets, and the boreal forest in the lower reaches of the forest have been reduced and converted largely to timber production, and (v) old growth forest has been reduced to less than 1% of its pre-EuroAmerican settlement extent. A total of 839 vascular plant species have been documented in the watershed, 747 of them during our survey. Additionally, we documented 233 species new to the watershed, of which 53 are new county records and 13 are listed as endangered, threatened, or special concern in Wisconsin. This study has shown that the Bois Brule River watershed harbors a diverse assemblage of plants and is worth further conservation action. It is recommended that additional survey work continue in the future to inform and guide land managers.

KEYWORDS: Flora of Wisconsin, land cover change, pre-settlement conditions, Brule River Survey.

---

* Data sets used in this article are available upon request from the Lake Superior Research Institute at the University of Wisconsin-Superior, Superior, Wisconsin.

† Author for correspondence (phlina4@gmail.com)

INTRODUCTION

This is the second of two articles (the first of which is Hlina et al. 2020) reporting on a three-year project to re-survey and analyze vegetative and land use changes in the exceptional Bois Brule River watershed in northwestern Wisconsin over the last 160 years. The watershed of the Bois Brule River (hereafter referred to as the Brule River) exhibits an exceptionally diverse array of habitat types and outstanding water resources that support fish and wildlife species and numerous rare flora and fauna. The watershed is on the southwest side of Lake Superior, in northwestern Wisconsin. The watershed crosses through three ecoregions: Lake Superior clay plains, covering the northern third, the Bayfield sand plains from the southwest to the northeast and the Milles Lacs uplands to the west. The consistent flow of cold waters of the Brule River moving through hundreds of feet of outwash sandy plains to arise on the valley floor is a product of the cedar swamps in the headwaters and groundwater-connected springs. The vegetative cover of the Brule River watershed is exceptional, with large tracts of lowland forest at the region of the headwaters and old growth pine forest extending to Winneboujou, an unincorporated community located where County Highway B crosses the Brule River. The narrowing lower reaches of the watershed consist of boreal forest heavily influenced by Lake Superior.

For more than a century, the Brule River has been recognized as one of the premier trout streams of the Upper Midwest, with presidents of the United States and influential families fishing its waters and occupying its shores. By the late 1930s, managers, residents, and visitors noticed a significant decline in the fisheries, even after in-stream improvements and heavy stocking programs. These early observations led to the first comprehensive study of the Brule River watershed in northwest Wisconsin. As Schneberger and Hasler (1944) noted:

> The need for an intensive study on this stream became evident when it was realized that during a five-year period extending from 1937 to 1941, a total of $34,247.67 was expended for the planting of fish and that stocking was not bringing about the desired results of maintaining or improving fishing.

The Brule River was studied from 1942–1945 and 1954 using a watershed approach. The Brule River Survey started in 1942 as a collaborative study conducted by the Wisconsin Conservation Commission, the University of Wisconsin-Madison, University of Wisconsin-Superior (then the Superior State Teacher's College), and private citizens (Schneberger and Hasler 1942). The survey examined the physical, biological, and chemical characteristics of the Brule River watershed and resulted in a series of eleven papers: Bean and Thomson (1944), Churchill (1945), Evans (1945), Fassett (1944), Fischthal (1945), O'Donnell (1944), O'Donnell (1945), O'Donnell and Churchill (1954), Schneberger and Hasler (1942), Thomson (1944), Thomson (1945).

The survey's objective was to pinpoint environmental disturbances that may be impacting fish populations. Botanists Norman Fassett and John Thomson conducted vegetative studies and floristic inventories of the Brule River valley and its forests, pine barrens, and wetland communities to document change and

provide baseline vegetative data. This work provided a critical view of the vegetation in the watershed in the early 1940s.

These earlier studies lend themselves to follow-up research to document vegetative changes, which we have now undertaken some seventy years later, the results of which are reported in this article. The objectives of this study were 1) to undertake a comprehensive floristic inventory of the forests of the Brule River watershed, focusing on complete species identification and voucher specimens, 2) to make qualitative summaries of floristic changes between our time and that of Fassett and Thomson, and 3) to characterize large-scale land cover changes in the watershed over three time periods: 1852–1856, 1932–1943, and 2014–2017.

METHODS AND MATERIALS

Study Site

The Brule River watershed is in northwestern Wisconsin, primarily in Douglas County with a short arm extending eastward into Bayfield County. The watershed consists of more than 51,300 ha of forests, barrens, lakes, spring ponds, and the Brule River itself, which traverses 71 km, including 32 km as a steep river gorge draining into Lake Superior. The river channel is remarkable in that it flows northeastward in the ancient channel of the much larger Glacial Lake Duluth outlet that in glacial times (approximately 9,500–10,000 years ago) flowed southwesterly in what is now the St. Croix River (Clayton 1984; LaBerge 1994). The headwaters of both rivers are in the Divide Swamp, which is part of the Brule Glacial Spillway State Natural Area. The Brule River State Forest follows the river gorge and consists of 19,020 ha of forest lands managed by the State of Wisconsin for harvest, management and protection. There are four state natural areas in the state forest: Brule Glacial Spillway 1,070 ha, Mott's Ravine 265 ha, Brule River Boreal Forest 263 ha and Brule Rush Lake 9 ha and 21 additional primary sites that offer further conservation potential within its boundaries (O'Connor 2016).

Between 2003 and 2016, more than 1,214 ha within the Brule River State Forest were removed from their earlier status as areas of priority conservation and restoration activities (O'Connor 2016). Simultaneously, the state of Wisconsin has recently increased timber production lands from 27% to 58% within the Brule River State Forest with most of the increase taken from the natural land's designation (Wisconsin Department of Natural Resources 2017). These policy shifts have a high potential to reverse natural succession away from multi-age and old growth forest communities with high diversity towards an earlier successional sere, thereby creating a greater likelihood of a simplified forest, which already occurs on 35% of the watershed.

Climate

The general climate of the watershed is continental. Based on weather data from Gordon, Wisconsin (located at the southern end of the watershed), the mean annual precipitation is 81 cm. On average, July is the wettest month with a mean of 11.4 cm of precipitation. The mean annual temperature is 5.0°C; July is the warmest month with a mean of 19.9°C, and January is the coldest with a mean of –12.3°C. The length of the frost-free growing season has ranged from 45 days to 145 days with an average of 118 days per year (Midwestern Regional Climate Center 2017a).

In contrast, the area of the watershed to the north is influenced by Lake Superior. The large body of water provides an oceanic-like microclimate that moderates the climate, making winters warmer and summers cooler in the areas near the lake. According to weather data from Superior, Wisconsin (located to the west of the watershed and on Lake Superior), the mean annual precipitation is 78 cm. On average, September is the wettest month with a mean of 10.4 cm of precipitation. The mean annual temperature is 5.2°; July is the warmest month with a mean of 19.1°C and January is the coldest with a mean of –10.1°C. The length of the frost-free growing season has ranged from 64 days to 189 days with an average of 148 days per year based on data collected from 1981 to 2010 (Midwestern Regional Climate Center 2017b).

The forests on the Brule River watershed exhibit responses to three microclimates that dictate forest composition. In the lower reaches of the river where forest is restricted to a narrow steep val-

ley and is influenced by the cooler temperatures of Lake Superior, boreal forest is found. Old growth coniferous bogs and swamps persist in the headwaters, where seepage springs deliver cool enriched mineral waters to a dense quagmire of *Thuja occidentalis*, *Picea mariana*, *Larix laricina*, and *Alnus incana*. Due to the foresight of early scientists and land managers, large tracts of this forest have been protected (Thomson 1945). The landscape rising above the middle reaches of the river exhibits yet a third microclimate, consisting of nutrient-poor, outwash glacial sand plains from the last glacial period (Sweet 1880; Clayton 1984; LaBerge 1994). In these pine barrens, drought resistant, fire-dependent species continue to shift through a mosaic of dwarf pine trees, scrub oaks, and open prairie. Today, most of this land consists of pine plantations (*Pinus banksiana* and *P. resinosa*) and is managed by private companies or state and county forest agencies.

Geology

The landscape of the watershed has been shaped by Precambrian lava flows, faulting, sedimentation, long epochs of erosion, and, finally, Pleistocene glaciation. Late in the Precambrian period, about 1.1 billion years ago, tectonic forces began rifting the North American craton (Laurentia), near present-day Lake Superior. The rifting extended 2,200 km southwest to present-day Kansas and 800 km southeast through present-day Michigan (Dott and Attig 2004). From these fissures, lava was released and spread across the region for millions of years. At the close of the Precambrian a shallow sea flooded the area laying down layers of sedimentary rocks. Over time these sediment deposits buried the underlying Keweenawan basalt. The sheer weight of the lava flows, and sediments formed the Lake Superior syncline, a down-warping of the earth's surface (Laberge 1994). Faulting would occur numerous times along the syncline. The Douglas Fault would later up-thrust the underlying basalt and distort the Keweenawan sandstones, creating the steep river valley in the lower reaches of the watershed (Bean and Thomson 1944, LaBerge 1994).

While these Precambrian events provide the underlying structure for the Brule River valley, a recent period of glaciation called the Wisconsinan, shaped the landscape with deposition of outwash sands and glacial till. Clayton (1984) describes numerous epochs of the ice sheets advancing and retreating. The last phase of the Wisconsinan glacial period occurred 25,000 years ago with the advancement of the Superior lobe. It scraped its way down the length of the valley that was to become the Lake Superior basin. Around twelve thousand years ago, Glacial Lake Duluth began to form, roughly 180 m higher than present-day Lake Superior. Over the next one thousand years, the Superior Lobe started melting for the final time. The initial meltwater formed a channel flowing from the southwest to the northeast. A spillway would eventually form to the south called the Brule/St. Croix spillway (Dott and Attig 2004). This new spillway would drain Glacial Lake Duluth to the south. Eventually (approx. 9,500 years ago), the continual erosive force of meltwater carved a deep channel that resulted in the stream flow reversing and now flowing northeast back to Glacial Lake Duluth. When the glaciers fully receded, a divide formed out of which the Brule and St. Croix rivers flow in opposite directions today (Bean and Thomson 1944).

Based on this geology and subsequent deposit of sediments, the Brule River watershed can be split into three main sections starting at the southwest and moving northeast.

1) At the headwaters of the watershed, the gradient is very gentle and flat. The river meanders slowly and arises out of a complex of conifer swamps dominated by *Thuja occidentalis, Larix laricina* and *Picea mariana*. Surrounding this boggy lowland, at least 30.5 m of outwash sands were deposited by streams draining the melting waters (Clayton 1984). Springs in the headwaters region are direct indications of the groundwater flow resulting from these outwash plains.

2) In the middle section of the river, the sandy outwash is reduced and replaced with glacial till and occasional sandstone outcrops (Bean and Thomson 1944). The sandstone exposures provide many of the rapids and falls seen in this section of the river. Many of the lakes present today (e.g., Lake Nebagamon and Lake Minnesuing) were likely depressions on the landscape prior to glaciation and that filled once the melting ice retreated (Clayton 1984). Additionally, this area of the valley readily stores water in hundreds of small wetlands.

3) Finally, in its lower reaches, the river flows through lacustrine deposits of red clay accumulated in Glacial Lake Duluth (9,500 years ago) (Clayton 1984). As the ice melted and retreated, clay deposits mixed with iron oxide were exposed, giving the soils their characteristic red brick color. Clay soils are characterized by the small grain size, a high water-holding capacity, and an elevated cation-exchange with nutrients in the soil (U.S. Environmental Protection Agency 1980). These heavy soils are impermeable, poorly drained, high in nutrients, and remain cool and moist throughout the grow-

TABLE 1. Number of floristic inventory survey sites in each forest community type. Thomson sites are the sites selected in the forest community types surveyed by Thomson (1945). New sites are the additional sites first surveyed in the present study.

Forest Community Type	Thomson Sites	New Sites	Total
Boreal Forest	6	4	10
Northern Dry Forest	–	5	5
Northern Dry-Mesic Forest	–	6	6
Northern Hardwood Swamp	6	1	7
Northern Mesic Forest	2	7	9
Northern Wet Forest	–	6	6
Northern Wet-Mesic Forest	3	9	12
Pine Barrens	4	2	6

ing season, which influences the species composition of the boreal forests they support (Epstein 2017).

Land Cover Analysis

To characterize the early vegetation of the Brule region, we used ArcGIS to digitize maps published by Fassett (1944) and Thomson (1945) that correspond to the time periods 1852–1856 and 1932–1943. We established a boundary of the current Brule River watershed based on recent elevation data using an automated watershed creation tool in ArcGIS. We cross-walked current land cover type information from Wiscland 2.0 data at a 600 dpi resolution (Wisconsin Department of Natural Resources 2016a) into the cover type categories used by Fassett (1944) and summarized the areas in each land cover type for all time periods as a way of inferring qualitative changes in the region. Strict area-based comparisons with early maps are subject to a moderate level of inaccuracy due to comparatively coarse tools used prior to the development of GIS; however, Thomson (1945) stated that the rates of error were below 7% for the early maps.

Floristic Inventories

Floristic inventories were conducted between May and September in 2015, 2016, and 2017 to document the flora of 61 sites, across eight terrestrial forest community types in the Brule River watershed: boreal forest, northern dry forest, northern dry-mesic forest, northern mesic forest, northern hardwood swamp, northern wet-mesic forest, northern wet forest and pine barrens (Table 1, Figure 1). These forest community types are described and classified in a Wisconsin Department of Natural Resources publication on Wisconsin's natural communities (Epstein 2017). In 2015–2017, 21 sites were chosen and surveyed in forested community types originally surveyed by Thomson (1945). Although Thomson (1945) did not disclose his site locations, we used geographical and locational information indicated on his more than 500 herbarium voucher specimens, which are in the Donald W. Davidson Herbarium at the University of Wisconsin-Superior (SUWS) and the Wisconsin State Herbarium at the University of Wisconsin-Madison (WIS). Sites were further refined by inspecting forest stand compartment maps from the Wisconsin Department of Natural Resources, followed by an on-site visit to confirm representative types.

Thomson's community species lists were created by assigning his herbarium specimens to specific forest community types. Additional species noted by Thomson (1944, 1945) but not represented by specimens were added to these community lists. Thomson combined northern wet-mesic and northern wet forest as conifer bog forest. We used his label information and our professional judgment to separate these communities into the northern wet and northern wet-mesic forest classification of today.

Forty additional sites were added to the study to provide a greater geographic representation of the eight forest types in the watershed. These sites were selected by viewing digital land cover maps to identify potential sites, followed by on-site visits to confirm representative habitats.

All sites were a minimum of five acres in size. Sites were selected if the following characteristics were evident: (i) boreal forest, a strong conifer component was present in the understory and the forest was approaching a mid-late successional sere; (ii) northern dry forest dominated by *Pinus banksiana* and *P. resinosa*, while devoid of *P. strobus*; (iii) northern dry-mesic forest, a component of

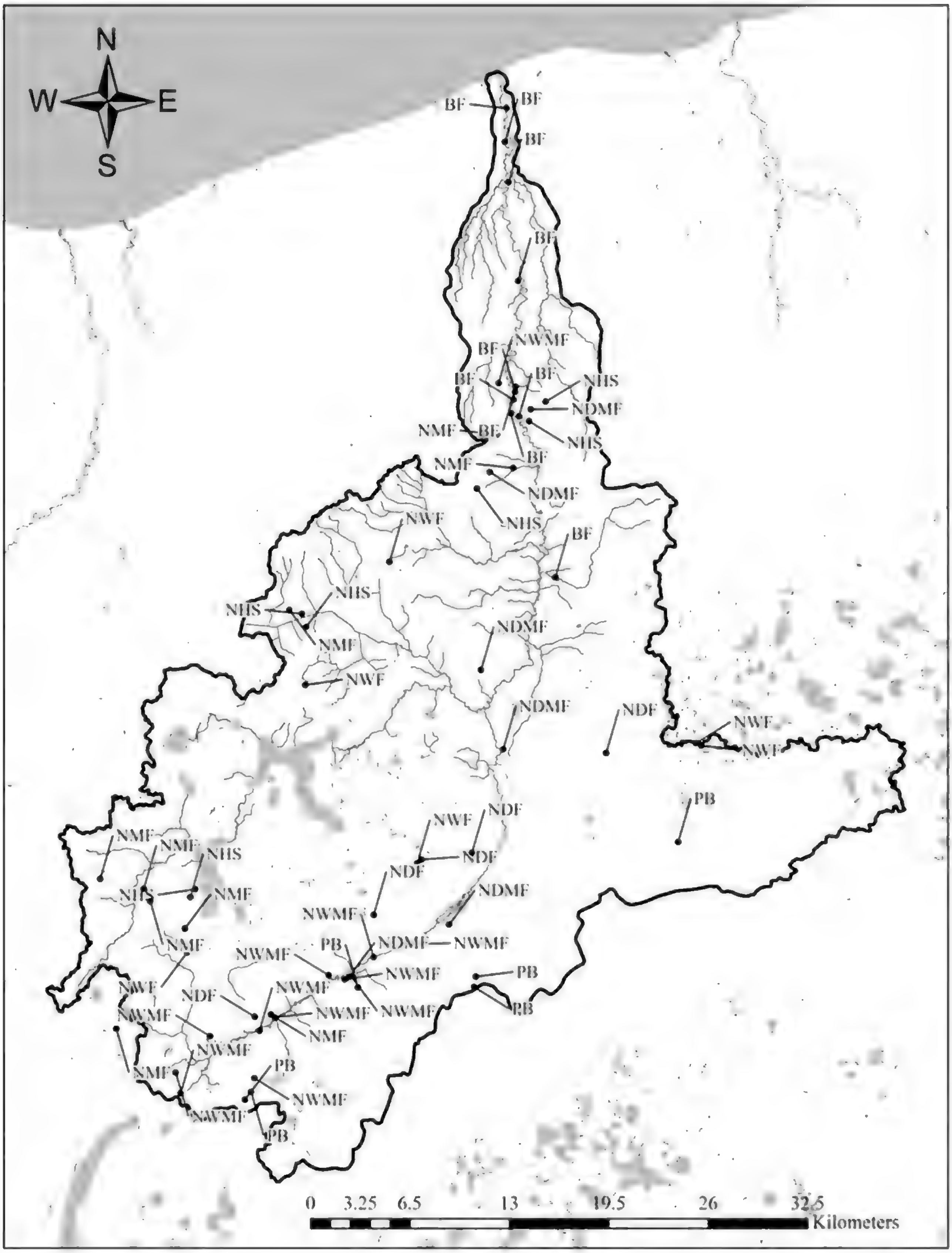

FIGURE 1. Brule river watershed. Survey sites are indicated by black dots, and the forest community type of each is indicated by the following codes: BF=boreal forest, NDF=northern dry forest, NDMF=northern dry-mesic forest, NHF=northern hardwood forest, NMF=northern mesic forest, NWF=northern wet forest, NWMF=northern wet-mesic forest, PB=pine barrens.

FIGURE 2. Northern wet-forest communities dominated by *Picea mariana* was one of the eight forest community types surveyed. Photo by Reed J. Schwarting.

Pinus strobus was found in the canopy, along with *Pinus resinosa* and/or *Pinus banksiana* as associates; (iv) northern hardwood swamps dominated by *Fraxinus nigra*; (v) northern mesic forest dominated by *Acer saccharum* or *Tsuga canadensis* with or without *Betula alleghaniensis*, *Fraxinus americana* or *Tilia americana*; (vi) northern wet forest dominated by *Picea mariana* or *Larix laricina*, with a canopy at least 6 m in height (Figure 2); (vii) northern wet-mesic forest dominated by *Thuja occidentalis*; and (viii) pine barrens consisted of mosaics of prairie-like openings, scrub oaks, and small stands of pines.

At each site, a floristic inventory was completed by a team of professional botanists from Illinois and Wisconsin. The team meandered through each site compiling a species list and collecting voucher specimens until no new species were observed (Figure 3). At the end of each survey, all observed species were assigned an abundance designation in one of four categories: abundant (A) = locally dominant species and those species that were widely distributed and often found growing in large quantities, common (C) = widely distributed and often found but not in abundant quantities, occasional (O) = not widespread but found in small numbers, rare (R) = rare to the site, only a small population or very few individuals found. These codes were applied to each site within a forest community type and then combined to create a complete species list for each community type. The abundance codes were applied subjectively by the team, but a conscientious effort was made for consistency. These descriptors are subjective estimates and should not be confused with quantitative cover values.

Voucher specimens were added to the archival Thomson collection housed at SUWS and the general herbarium collection at WIS (Figure 4). Duplicates were prepared and given to the Illinois Natural History Survey Herbarium (ILLS). Nomenclature primarily follows Voss and Reznicek (2012), which includes most Wisconsin species. Judziewicz et al. (2014) was used for all the grass species and for those species not included, the Flora of North America (Flora of North America Editorial Committee 1993+) was consulted.

Additional surveys were conducted at known and potential localities for rare and notable plants

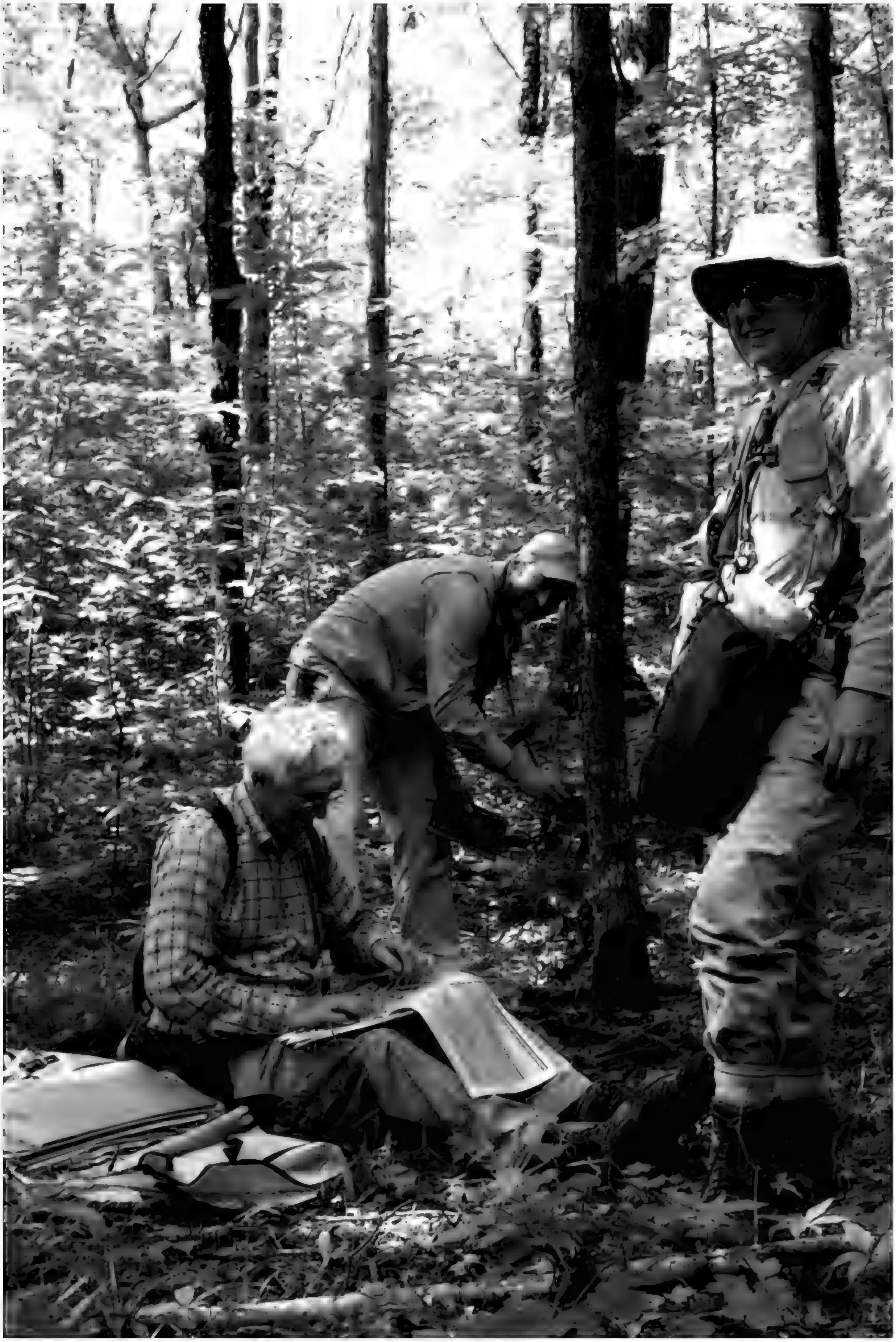

FIGURE 3. Field team of Paul Marcum, Loy R. Phillippe, and Mary Ann Feist collecting voucher specimens to add to the Thomson archival collection. Photo by Derek S. Anderson.

FIGURE 4. *Heuchera richardsonii*. A July 1943 Brule River Survey collection by Dr. John Thomson found in the pine barrens community at the abandoned Volker farm field. It was preserved specimens like these that narrowed our designated sites for repeat surveys. Digital image from Univesity of Wisconsin-Superior, Superior.

of the watershed. Rare plants included any plant species listed on the Wisconsin Natural Heritage Working List (Wisconsin Department of Natural Resources 2016d). Notable species are uncommon species found for the first time in the watershed and may also be new to Douglas County. Rare and notable plant populations were identified and documented by recording latitude and longitude, population size, phenology, and site characteristics and by taking photographs.

Analysis

We calculated various statistics to characterize the flora within each forest community type and made comparisons with similar calculations that we applied to Thomson's data and voucher specimens for each forest community type (Thomson 1944, Thomson 1945). Such comparisons were made for all community types except northern dry forest and northern dry-mesic forest, which had few representative sites remaining in the watershed. We calculated average species richness per site and total species richness across all sites within each community as a basic measure of floristic diversity.

A floristic quality assessment (FQA) was used to provide an ecological condition assessment based on all species in the forest. This assessment was originally developed in the late 1970's in the Chicago region to identify protection-worthy lands with a simple, repeatable, quantitative method (Swink and Wilhelm 1979). They assigned a Coefficient of Conservatism (C), a number from 0 to 10 for each species representing the Illinois flora. In the early 2000's, Wisconsin's expert botanists convened and did the same for Wisconsin's vascular plants (Bernthal 2003). This list is now maintained by the Wisconsin Department of Natural Resources (Wisconsin Department of Natural Resources 2016c).

The FQA relies on two measurements, the Mean C and the Floristic Quality Index (FQI). The FQI is sensitive to the total hectares surveyed as species richness increases as the sample area increases (Matthews 2005). We were unable to determine Thomson's sample areas in 1944–45 and chose the Mean C as a reliable metric in comparing the two time periods at the forest community scale. Species that are relatively tolerant of anthropogenic disturbance have low C-values, whereas species that are less tolerant of anthropogenic disturbance have high C-values (Spyreas 2019). We calculated a Mean Coefficient of Conservatism (*C*) for each forest type community. *Mean C* is the

arithmetic average of the *C* values across the total number of plant species observed (*n*) by the cumulative surveys by forest type. We calculated versions of *C* for all species (*Ct*) and for native species only (*Cn*). Since non-native species have a Coefficient of Conservatism of zero, *Ct* will always be less than *Cn*.

$$\bar{C} = (C_1 + C_2 + C_3 + \cdots + C_n) \div n$$

Further, we determined the percentage of non-native species, as well as the presence and abundance of prevalent ground layer species. In each forest community type, we classified prevalent ground layer species as those found in 80% or more of the surveyed sites with an abundance code of (A) or (C) in at least 50% of them. Most prevalent ground layer species are those with an abundance code of (A) or (C) and occur in 80% or more of the surveyed sites.

We used Sørensen Similarity Coefficients (Sørensen 1948) to identify sites that were compositionally dissimilar from others in their corresponding forest community type. The calculated coefficient ranges from 0 to 1, where a higher value indicates a higher percentage of shared species between the two sites. We calculated the coefficient for all pairs of sites within each forest community type. We removed sites in each community type where the coefficient was less than 0.4 from further comparisons. This process resulted in the removal of three sites that were likely misclassified, one each from the northern wet-mesic forest, northern hardwood swamp, and pine barrens communities.

RESULTS

Vegetation Cover Map Analysis (1852–2017)

As with all regions throughout the Midwest, land cover changes over the past 160 years have been substantial in the Brule River watershed. Today public lands encompass 60% (30,729 ha) of the watershed and include: Brule River State Forest, Douglas County Forestry and Parks and Bayfield County Forestry. The remaining 40% (20,570 ha) of the land in the watershed is controlled by private land holdings including timber management, logging companies and shoreline and streambank landowners. Based on comparisons of land cover maps across time periods (Table 2, Figure 5), we noted five general trends:

1. There was a shift from open pine barrens and dry forest to managed pine plantation in the southeastern extent of the watershed. These pine barrens declined from over 16,187 ha in 1852–1856 and 12,140 ha in 1932–43 to approximately 908 ha today.

2. Old-growth (northern dry-mesic forest) had been reduced by 75% of its pre-EuroAmerican settlement coverage by the 1940s. As a result of private and public protection of these old growth forests in land trusts and managed natural lands there has been a slight rebound with 2.6% (1,325 ha) of land represented in the watershed.

3. The early surveys depict a narrow strip of northern wet-mesic forest surrounding the Brule River from the headwaters area extending northeast up to Big Lake (Thomson 1945). Thomson (1945) noticed on-going harvesting in this forest in the 1940s that resulted in a substantial narrowing of this band. In 1945, the Brule River State Forest expanded its boundaries to include these headwater

TABLE 2. Land cover area of historical community types and their current equivalents in three different time periods, illustrating vegetation changes in the Brule River watershed. The cover area for 1852–1856 and 1932–1943 were mapped originally in Fassett (1944) and are digitized for our comparisons here. The areas in the column headed 2014–2016 (Fassett) were determined using Wiscland 2.0 and cross-walked to Fassett's cover types. The areas in the column headed 2014–2016 (Current) refer to Epstein's (2017) natural communities' classification in discussing the eight forested communities in the watershed.

Historical Mapped Community Classification	Land Cover in hectares				Current Community Classification
	1852–1856	1932–1943	2014–2016 (Fassett)	2014–2016 (Current)	
Aspen	7609	15168	13529	13302	Northern hardwood aspen
				226	Northern hardwood oak-maple
Bog conifer	6702	3571	3401	971	Northern wet-mesic forest
				1936	Northern wet forest
				495	Muskeg
Lowland hardwood	230	4988	5420	5420	Northern hardwood swamp
Maple-yellow birch	924	192	750	750	Northern mesic forest
Pine forest	3649	881	17293	2649	Northern dry-mesic forest
				14644	Northern dry forest – pine plantation
Pine-hardwood	6717	2096	4480	4480	Northern mixed/conifer hardwood
Pine barren	16882	12285	908	908	Pine barren
Spruce-fir forest	3413	432	1877	1877	Boreal forest
Cleared	0	4010	2165	427	Developed
				1725	Agriculture
Willow, alders, etc.	0	59	574	273	Alder thicket
				44.5	Northern wet meadow
Marsh	85			13	Shrub carr
				244	Open bog
Open water	1490	1482	915	915	Open water
Maple coppice	45	642	0		
Small fir & aspen	0	1248	0		
Totals	**47054**	**47768**	**51312**	**51300**	

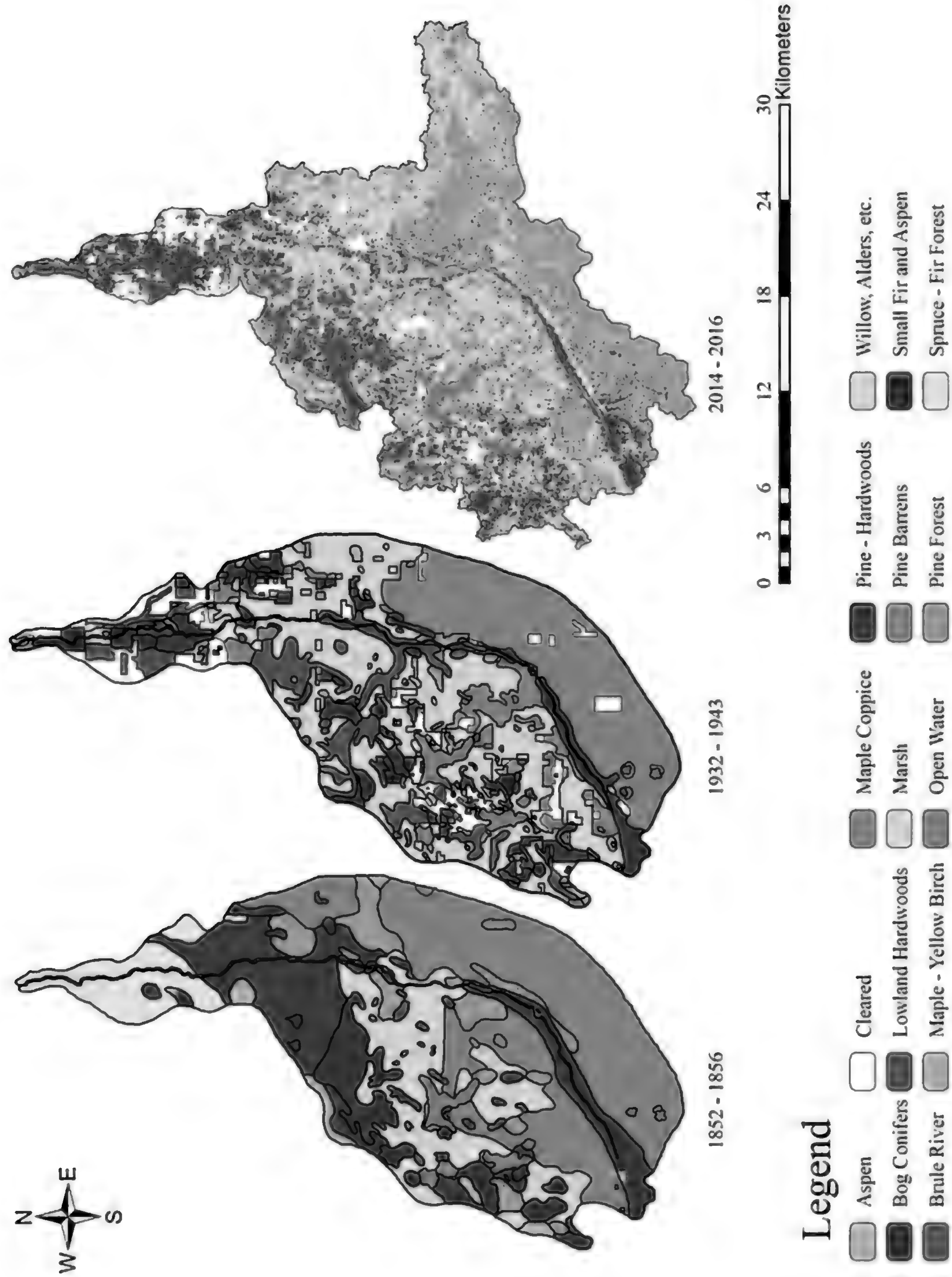

FIGURE 5. Land cover changes in the Brule River watershed from 1852 to 2016.

forests, offering protection and management (Wisconsin Department of Natural Resources 2017).

4. A large conifer bog complex north of Lake Nebagamon was depicted on the 1852–1856 map. By the 1940s, there was a substantial decline from *Thuja occidentalis* to a lower quality forest of northern hardwood swamps dominated by *Fraxinus nigra* and *Alnus incana*. Remnants of the original forest are present, but in even smaller parcels.

5. Boreal forest extending from the mouth of the river towards the southwest has been greatly diminished, though recovery is occurring, and some stands are approaching old growth. Substantial forest lands were initially cleared for farming, while thousands of hectares have been placed into managed timber production consisting primarily of *Populus* spp., *Quercus* spp. and *Acer* spp.

Forest Inventory Summaries

During his surveys in 1944 and 1945, Thomson collected 523 specimens representing 376 species. In this study, surveying in similar forest community types but with greater sampling effort, we collected over 2,200 specimens representing 747 species (16.6% of them non-native). A review of Thomson's collections and other herbarium records revealed documented records of 92 species not found during our surveys. These are listed in Table 3. This brings the total of species documented for the watershed to 839. From our surveys, we recorded 53 new records for Douglas County (17% of them non-native species) (Table 4, Figure 6). Further, we collected 233 species (5% of them non-native) from the Brule River watershed for the first time. Three concurrent studies on the watershed were further referenced (Hlina et al. 2018a; Hlina et al. 2018b; Schwarting et al. 2018) in creating the comprehensive species list of the Brule River watershed in Appendix 1. An additional 18 species (Table 5) were seen and recorded in these studies but we failed to collect, and no historical herbarium records were found; therefore, these species are not included in the comprehensive species list (Appendix 1). Thomson vouchered enough species from the boreal forest, northern wet-mesic forest, pine barrens, northern hardwood swamps, northern mesic forest, and northern wet forest communities for us to compare his collection data with our observed and vouchered specimens.

Boreal forest averaged 132 species per site, with a range of 93–182 species. Dominant tree species include *Populus tremuloides, Abies balsamea, Picea glauca*, and *Pinus strobus.* Community richness was 66 families, 192 genera, 362 species of which 14.9% are non-native. The five most dominant families were Cyperaceae (11%), Asteraceae (10%), Rosaceae (8%), Poaceae (8%) and Ranunculaceae (5%). Twelve prevalent ground layer species were recorded (Appendix 2), with four species being most prevalent: *Eurybia macrophylla*, *Maianthemum canadense*, *Pteridium aquilinum*, and *Aralia nudicaulis*. Thomson's community richness consisted of 38 families, 79 genera, and 105 species, 5% of which are non-native (Thomson 1945). Seventy-nine percent of prevalent species were also surveyed by Thomson. The value for *Cn* was 5.3, as compared to 4.9 for Thomson's survey, while *Ct* was 4.5, as compared to 4.7 (Figure 7).

TABLE 3. Plant taxa previously documented from the Brule River Watershed but not encountered during the 2015–2016 survey. Non-native species are indicated with an asterisk (*). *Tephroseris palustris* is listed in Wisconsin as Special Concern and was last seen in the watershed by L.S. Cheney in 1897.

Family	Species
	PTERIDOPHYTES
Cystopteridaceae	*Cystopteris tenuis*
Equisetaceae	*Equisetum ×ferrissii*
Lycopodiaceae	*Dendrolycopodium obscurum*
Lycopodiaceae	*Huperzia selago*
Lycopodiaceae	*Lycopodiella inundata*
Ophioglossaceae	*Botrychium lanceolatum*
Ophioglossaceae	*Sceptridium multifidum*
	DICOTS
Amaranthaceae	* *Froelichia gracilis*
Anacardiaceae	*Rhus × pulvinata*
Apiaceae	* *Pastinaca sativa*
Apiaceae	*Sanicula odorata*
Araliaceae	*Aralia hispida*
Asteraceae	* *Achillea ptarmica*
Asteraceae	*Ambrosia psilostachya*
Asteraceae	* *Artemisia pontica*
Asteraceae	* *Artemisia vulgaris*
Asteraceae	* *Centaurea jacea*
Asteraceae	*Cirsium discolor*
Asteraceae	* *Crepis tectorum*
Asteraceae	* *Grindelia squarrosa*
Asteraceae	*Liatris ligulistylis*
Asteraceae	*Rudbeckia laciniata*
Asteraceae	*Symphyotrichum boreale*
Asteraceae	*Symphyotrichum pilosum*
Asteraceae	*Tephroseris palustris*
Betulaceae	*Alnus viridis*
Boraginaceae	*Lithospermum caroliniense*
Boraginaceae	* *Lithospermum officinale*
Brassicaceae	* *Erysimum cheiranthoides*
Brassicaceae	*Rorippa palustris*
Brassicaceae	* *Sisymbrium altissimum*
Brassicaceae	* *Thlaspi arvense*
Caprifoliaceae	*Symphoricarpos occidentalis*
Caryophyllaceae	* *Silene dichotoma*
Caryophyllaceae	* *Stellaria borealis*
Caryophyllaceae	* *Stellaria graminea*
Fabaceae	*Lespedeza capitata*
Fabaceae	* *Robina pseudoaccacia*
Fabaceae	* *Trifolium campestre*
Fabaceae	* *Trifolium pratense*
Fabaceae	* *Vicia villosa*
Gentianaceae	*Gentiana rubricaulis*
Lamiaceae	* *Ajuga genevensis*
Linderiaceae	*Lindernia dubia*
Molluginaceae	* *Mollugo verticillata*
Onagraceae	*Oenothera perennis*
Penthoraceae	*Penthorum sedoides*
Plantaginaceae	* *Linaria vulgaris*

(Continued on next page)

TABLE 3. (*Continued*)

Family	Species
Plantaginaceae	*Nuttallanthus canadensis*
Plantaginaceae	*Veronica peregrina*
Plantaginaceae	* *Veronica serphyllifolia*
Polygalaceae	*Polygala sanguinea*
Polygonaceae	*Polygonum achoreum*
Polygonaceae	* *Polygonum aviculare*
Portulaceae	* *Portulaca oleracea*
Ranunculaceae	*Clematis occidentalis*
Rhamnaceae	*Ceanothus americanus*
Rosaceae	*Agrimonia striata*
Rosaceae	*Aronia × prunifolia*
Rosaceae	*Crataegus succulenta var. macracantha*
Rosaceae	* *Filipendula rubra*
Salicaceae	* *Salix alba*
Urticaceae	*Urtica dioica*
	MONOCOTS
Alismataceae	*Alisma triviale*
Alismataceae	*Sagittaria cuneata*
Convallariaceae	*Maianthemum stellatum*
Cyperaceae	*Carex arcta*
Cyperaceae	*Carex cryptolepis*
Cyperaceae	*Carex houghtoniana*
Cyperaceae	*Carex lurida*
Cyperaceae	*Carex pellita*
Cyperaceae	*Cyperus lupulina*
Cyperaceae	*Eleocharis obtusa*
Cyperaceae	*Schoenoplectus pungens*
Cyperaceae	*Scirpus microcarpus*
Eriocaulaceae	*Eriocaulon aquaticum*
Hydrocharitaceae	*Elodea nuttallii*
Juncaceae	*Juncus balticus*
Juncaceae	*Juncus interior*
Juncaceae	*Juncus vaseyi*
Orchidaceae	*Calopogon tuberosus*
Orchidaceae	*Goodyera pubescens*
Orchidaceae	*Malaxis unifolia*
Orchidaceae	*Plantathera clavellata*
Poaceae	*Agrostis hyemalis*
Poaceae	*Alopecurus aequalis*
Poaceae	*Ammophila breviligulata*
Poaceae	*Dichanthelium columbianum*
Poaceae	* *Echinochloa crusgalli*
Poaceae	*Eragrostis hypnoides*
Poaceae	* *Poa annua*
Potamogetonaceae	*Stuckenia filiformis*

TABLE 4. New vascular plant records for Douglas County. Non-native species are indicated by an asterisk (*). The Douglas County collection of Lactuca hirsuta is the second known collection from the state of Wisconsin.

Family	Taxon
Asteraceae	*Bidens discoidea*
Asteraceae	*Helianthus hirsutus*
Asteraceae	**Hieracium lachenalia*
Asteraceae	*Lactuca hirsuta*
Asteraceae	*Krigia biflora*
Asteraceae	*Pseudognaphalium obtusifolium*
Asteraceae	*Symphyotrichum urophyllum*
Boraginaceae	* *Myosotis arvensis*
Brassicaceae	*Cardamine pratensis var. palustris*
Caprifoliaceae	*Triosteum aurantiacum*
Caryophyllaceae	* *Arenaria serpyllifolia*
Caryophyllaceae	* *Dianthus barbatus*
Caryophyllaceae	* *Gypsophila muralis*
Caryophyllaceae	*Moehringia lateriflora*
Caryophyllaceae	* *Spergularia rubra*
Cyperaceae	*Carex alopecoidea*
Cyperaceae	*Carex backii*
Cyperaceae	*Carex bromoides var. bromoides*
Cyperaceae	*Carex echinodes*
Cyperaceae	*Carex hirtifolia*
Cyperaceae	*Carex muehlenbergii*
Cyperaceae	*Carex normalis*
Cyperaceae	*Carex ormostachya*
Cyperaceae	*Carex radiata*
Cyperaceae	*Carex rosea*
Cyperaceae	*Carex sprengelii*
Cyperaceae	*Carex tribuloides*
Cyperaceae	*Carex × knieskernii*
Droseraceae	*Drosera intermedia*
Ericaceae	*Pyrola americana*
Fabaceae	*Hylodesmum glutinosum*
Fabaceae	* *Vicia cracca*
Gentianaceae	*Gentiana alba*
Grossulariaceae	*Ribes lacustre*
Hemerocallidaceae	* *Hemerocallis fulva*
Juncaceae	*Juncus brachycephalus*
Lamiaceae	*Clinopodium vulgare*
Lythraceae	*Decodon verticillatus*
Onagraceae	*Oenothera clelandii*
Orobanchaceae	*Conopholis americana*
Plantaginaceae	*Plantago rugelii*
Plantaginaceae	* *Veronica longifolia*
Poaceae	*Bromus latiglumis*
Poaceae	*Bromus pubescens*
Poaceae	*Cinna arundinacea*
Poaceae	*Dichanthelium linearifolium*
Poaceae	*Dichanthelium oligosanthes*
Poaceae	*Elymus wiegandii*
Poaceae	*Torreyochloa pallida*
Potamogetonaceae	*Potamogeton nodosus*
Potamogetonaceae	*Potamogeton oakesianus*
Rosaceae	*Crataegus submollis*
Smilacaceae	*Smilax illinoensis*

FIGURE 6. *Conopholis americana*, one of 53 new county records for Douglas County in northwestern Wisconsin. Photo by Derek S. Anderson.

TABLE 5. Species seen during this study but not vouchered and for which no herbarium records from the Brule River watershed are known. An asterisk (*) indicates a non-native species.

Family	Species
Apiaceae	*Osmorhiza longistylis*
Asteraceae	*Erigeron philadelphicus*
Asteraceae	*Helianthus pauciflorus*
Asteraceae	*Heliopsis helianthoides*
Brassicaceae	*Boechera grahamii*
Brassicaceae	*Cardamine diphylla*
Cyperaceae	*Carex blanda*
Cyperaceae	*Carex laxiflora*
Cyperaceae	*Cyperus schweinitzii*
Fabaceae	*Dalea purpurea*
Lamiaceae	* *Nepeta cataria*
Orchidaceae	*Spiranthes cernua*
Poaceae	*Elymus villosus*
Ranunculaceae	*Anemone acutiloba*
Rosaceae	* *Pyrus communis*
Salicaceae	*Salix nigra*
Smilacaceae	*Smilax ecirrhata*
Vitaceae	*Vitis riparia*

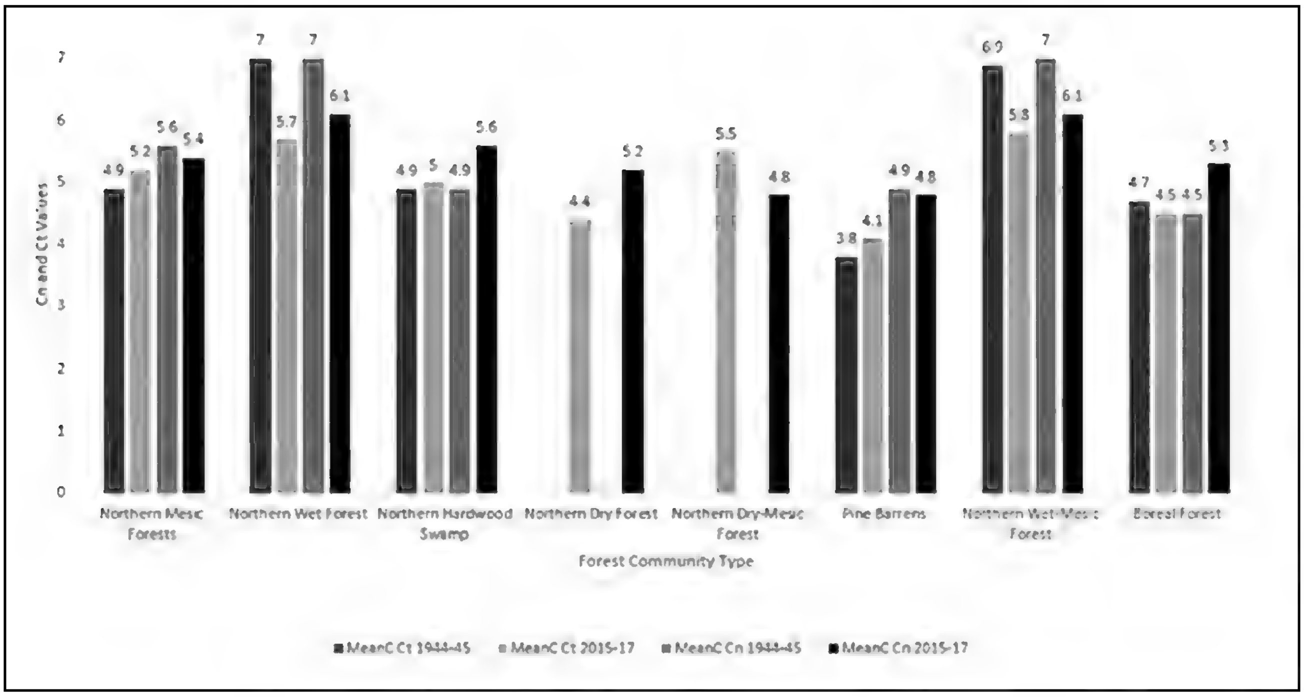

FIGURE 7. *Ct* and *Cn* values compared with the Thomson data of 1944–45. There was no comparison data for the northern dry and northern dry-mesic forests communities, as these were not forest types that Thomson recognized.

Northern wet-mesic forest averaged 98 species per site, with a range of 67–125 species. Dominant tree species include *Thuja occidentalis* and *Abies balsamea*. Community richness consisted of 64 families, 163 genera and 299 species, of which 4.3% are non-native. The five dominant families were Cyperaceae (12.3%), Asteraceae (8%), Rosaceae (7%), Ericaceae (6%) and Poaceae (5%). Eleven prevalent ground layer species were recorded (Appendix 2), with five species being most prevalent: *Rubus pubescens*, *Coptis trifolia*, *Maianthemum canadense*, *Trientalis borealis*, and *Cornus canadensis*. Thomson's community richness consisted of 40 families, 71 genera, and 83 species, of which 3% were non-native (Thomson 1945). Eighty percent of prevalent species we recorded were also surveyed by Thomson. The value for *Cn* was 6.1, as compared to 6.9 for Thomson's survey, while *Ct* was 5.7, as compared with 6.7 (Figure 7).

Pine barrens averaged 87 species per site, with a range of 62–111 species. Dominant tree species included *Pinus resinosa* and *Pinus banksiana*. Community richness consisted of 54 families, 137 genera, and 207 species, of which 16.4% are non-native. The four dominant families were Asteraceae (20%), Poaceae (13.8%), Rosaceae (10.5%), and Cyperaceae (5.7%). Sixteen prevalent ground layer species were recorded (Appendix 2), with eleven species being most prevalent: *Comptonia peregrina*, *Corylus americana*, *Prunus pumila*, *Rubus flagellaris*, *Carex pensylvanica*, *Vaccinium angustifolium*, *Quercus macrocarpa*, *Quercus ellipsoidalis*, *Andropogon gerardii*, *Danthonia spicata*, and *Monarda fistulosa*. Thomson's community richness consisted of 39 families, 94 genera, and 127 species, of which 17% were non-native (Thomson 1945). Sixty-three percent of prevalent species recorded, were also surveyed by Thom-

son. *Cn* was 4.8, compared to 4.9 from Thomson's survey. *Ct* was 4.1, compared to 4.0 (Figure 7).

Northern hardwood swamp averaged 93 species per site, with a range of 71–130 species. Dominant tree species included *Fraxinus nigra* and *Thuja occidentalis*. Community richness consisted of 66 families, 170 genera, and 307 species, of which 10.7% are non-native. The four dominant families were Cyperaceae (13%), Asteraceae (9%), Poaceae (8%), and Rosaceae (7%). Ten prevalent ground layer species were recorded (Appendix 2), with four species being most prevalent: *Carex stipata*, *Rubus pubescens*, *Carex intumescens*, and*, Onoclea sensibilis*. Thomson's community richness consisted of 33 families, 47 genera, and 52 species with no non-native species (Thomson 1945). Twenty-five percent of our prevalent species were also surveyed by Thomson. *Cn* was 5.6 compared to 4.9 in Thomson's. *Ct* was 5.0 compared to 4.9 (Figure 7).

Northern wet forest averaged 36 species per site, with a range of 23–71 species. Dominant tree species included *Picea mariana* and *Larix laricina*. Community richness consisted of 44 families, 93 genera, and 156 species, of which 6.4% were non-native. The five dominant families were Cyperaceae (18%), Rosaceae (11%), Ericaceae (7%), Asteraceae (6%), and Poaceae (6%). Four prevalent ground layer species were recorded (Appendix 2), with two species being the most prevalent: *Rhododendron groenlandicum* and *Maianthemum trifolium*. Thomson's community richness consisted of 16 families, 25 genera, and 34 species with no non-native species (Thomson 1945). One hundred percent of our prevalent species were also surveyed by Thomson. *Cn* was 6.1, compared to 7.0 in Thomson's survey. *Ct* was 5.7, compared to 7.0 (Figure 7).

Northern mesic forest averaged 85 species per site, with a range of 42–144 species. Dominant tree species included *Acer saccharum*, *Tilia americana*, and *Acer rubrum*. Community richness consisted of 59 families, 147 genera, and 242 species, of which 10% were non-native. The five dominant families were Cyperaceae (11%), Poaceae (9%), Asteraceae (8%), Rosaceae (7%), and Ranunculaceae (6%). Six prevalent ground layer species were recorded (Appendix 2), with three species being most prevalent: *Acer saccharum*, *Maianthemum canadense*, and *Clintonia borealis*. Thomson's community richness consisted of 31 families, 45 genera, and 59 species, of which 3% were non-native (Thomson 1945). Eighty-three percent of our prevalent species were also surveyed by Thomson. *Cn* was 5.6 for both time periods. *Ct* was 4.9, compared to 5.5 in Thomson's survey (Figure 7).

Although we could not do comparisons for the remaining forest types, we provide summary data from our surveys for two additional forest types. Northern dry forest averaged 75 species per site, with a range of 45–111 species. Dominant tree species included *Pinus resinosa* and *P. banksiana*. Community richness consisted of 51 families, 134 genera, and 209 species, of which 15.8% were non-native. The five dominant families were Asteraceae (11%), Poaceae (11%), Rosaceae (11%), Cyperaceae (6%), and Ericaceae (6%). Seven prevalent ground layer species were recorded (Appendix 2), with three species being most prevalent: *Maianthemum canadense*, *Pteridium aquilinum*, and *Oryzopsis asperifolia*. *Cn* for all northern dry forest species was 5.2, while *Ct* was 4.4 (Figure 7).

Northern dry-mesic forest averaged 94 species per site, with a range of 39–128 species. Dominant tree species included *Pinus resinosa*, *P. banksiana*, *P. strobus*, and *Betula papyrifera.* Community richness consisted of 65 families, 163 genera, and 263 species, of which 12.9% were non-native. The five dominant families were Asteraceae (10%), Rosaceae (9%), Poaceae (8%), Cyperaceae (6%), and Ericaceae (5%). Seven prevalent ground layer species were recorded (Appendix 2), with four species being most prevalent: *Maianthemum canadense*, *Pteridium aquilinum*, *Aralia nudicaulis*, and *Eurybia macrophylla*. *Cn* was 5.5, while *Ct* was 4.8 (Figure 7).

The following species were documented by Thomson (1945), but not found by our 2015–2017 surveys: *Agrimonia striata*, *Alnus viridis*, *Botrychium lanceolatum*, *B. matricariifolium*, *Botrypus virginianus*, *Calopogon tuberosus, Carex retrorsa*, *Celastrus scandens*, *Clematis occidentalis, Geum fragarioides*, *Grindelia squarrosa*, *Liatris ligulistylis*, *Nuttallanthus canadensis*, *Osmorhiza longistylis*, *Rudbeckia laciniata, Symphoricarpos occidentalis*, *Symphyotrichum boreale*.

Among various plant growth forms, graminoid species displayed substantial proportional compositional increases between the two time periods (1945, 2017) in the boreal forest, northern hardwood swamp and northern wet-mesic forest, while there was only a slight increase of graminoids in the northern mesic forest. There was no change in plant growth forms for the pine barrens and northern wet forest (Table 6).

Appendix 3 summarizes these details for all forest types surveyed.

Rare and Notable Species

Between 2015 and 2017, we found thirteen species listed as rare in Wisconsin (Wisconsin Department of Natural Resources 2016c): *Asclepias ovalifolia* (Figure 8), *Callitriche hermaphroditica*, *Calypso bulbosa*, *Carex backii, Coptidium lapponicum*, *Cypripedium parviflorum* var. *makasin*, *Eriophorum chamissonis* (Figure 9), *Geum macrophyllum* var. *macrophyllum*, *Petasites frigidus* var. *sagittatus*, *Pyrola minor*, *Ribes oxyacanthoides*, *Rhynchospora fusca*, and *Vaccinium vitis-idaea*. Six rare species were found in the northern wet-mesic forest, four in the boreal forest, one in the pine barrens, one in the northern hardwood swamp and one in the northern wet forest. These areas may be the last refuge in the Brule River watershed, if not in the State of Wisconsin, for the species *Coptidium lapponicus* and *Calypso bulbosa* and many other rare plant assemblages. An additional ten notable species with low occurrences were added to the list (Table 7).

DISCUSSION

We could not determine the exact methods that Thomson (1944, 1945) used to survey the flora of each of these communities. Upon close examination of his herbarium specimens and his papers (Thomson, 1944; Thomson 1945), it

TABLE 6. Number of species of five growth forms represented in species lists for 1944–1945 and 2015–2016 in each of the eight forest community types. Data for 1944–1945 are omitted for northern dry forests and northern dry-mesic forests due to lack of historical data.

	1944–1945		2015–2016	
Growth Form	Number of Species	Percentage (%)	Number of Species	Percentage (%)
Boreal forest				
Tree	16	15	25	7
Shrub	21	21	62	17
Forb	57	54	198	55
Graminoid	8	8	70	19
Vine	3	3	7	2
Totals	105	100	362	100
Northern wet-mesic forest				
Tree	6	7	19	6
Shrub	14	17	57	19
Forb	55	67	162	54
Graminoid	8	9	57	19
Vine	0	0	4	2
Totals	83	100	299	100
Pine barrens				
Tree	7	6	13	6
Shrub	19	15	28	14
Forb	81	64	121	58
Graminoid	18	14	43	21
Vine	1	1	2	1
Totals	126	100	207	100
Northern hardwood swamp				
Tree	8	15	20	7
Shrub	7	13	51	16
Forb	33	64	167	54
Graminoid	2	4	64	21
Vine	2	4	5	2
Totals	52	100		100
Northern mesic forests				
Tree	8	13	18	7
Shrub	8	14	44	18
Forb	34	58	126	53
Graminoid	8	14	51	21
Vine	1	1	1	1
Totals	59	100	242	100

(*Continued on next page*)

TABLE 6. (*Continued*)

Growth Form	1944–1945 Number of Species	1944–1945 Percentage (%)	2015–2016 Number of Species	2015–2016 Percentage (%)
Northern wet forest				
Tree	7	21	13	8
Shrub	9	26	38	24
Forb	10	29	65	42
Graminoid	8	24	40	26
Vine	0	0	0	0
Totals	34	100	156	100
Northern dry forest				
Tree			15	7
Shrub			43	21
Forb			105	50
Graminoid			46	22
Vine			0	0
Totals			209	100
Northern dry-mesic forest				
Tree			24	9
Shrub			51	19
Forb			143	54
Graminoid			41	16
Vine			4	2
Totals			263	100

appears that Thomson may have had some bias towards collecting along roadways and in abandoned fields. Furthermore, Thomson collected on his own on 53 field days spanning a three-year period, whereas our research teams consisted of groups of surveyors and professional botanists surveying the equivalent of 180 field days spanning a three-year period. The level of effort far exceeded Thomson's and has likely contributed to the discrepancy between the measurements of species richness, species composition, and species abundance for the two time periods.

When examining changes in the function, structure, and growth of the groundcover stratum, a clear pattern emerges. First, the graminoids have become more dominant throughout several forest types (Table 6). Recent authors (Rooney and Waller 2003; Rooney 2009; Burton et al. 2014) suggest that graminoids are better able to recover from browsing pressure than most forbs, which leads to their increased dominance in today's forests because of an increase in herbivory by white-tailed deer. A second trend observed was an increase in the total number of tree species in most forest types (Table 6), while species percentages as a portion of forest composition remained the same across all community types. A likely explanation is the exhaustive nature of our studies

FIGURE 8. *Asclepias ovalifolia* in a population of more than 200 individuals located in a recently harvested pine plantation in the pine barrens community type. Photo by Derek S. Anderson.

FIGURE 9. *Eriophorum chamissonis* in a population of hundreds found in one small bog near the shores of Lake Nebagamon in the western portion of the watershed. Photo by Reed J. Schwarting.

TABLE 7. Rare, threatened, endangered species in the watershed. Also included in the list are notable species which are uncommon species found for the first time in the watershed and may also be a new Douglas County record. In the State Status column, SC = Special Concern, THR = Threatened, END = Endangered, N = Notable.

	Number of Occurrences	Year Last Observed	State Status	Comments
Asclepias ovalifolia	1	2015	THR	100 plants
Callitriche hermaphroditica	4	2016	SC	cold spring waters
Calypso bulbosa var. *bulbosa*	2	2016	THR	125 plants in 1996; two plants in 2016
Carex assiniboienensis	1	2016	N	boreal tributary ravine
Carex backii	2	2015	SC	bedrock glade
Carex vaginata	Several	2016	N	scattered
Carex × *knieskernii*	1	2016	N	several plants
Coptidium lapponicus	3	2015	END	>250 plants
Cypripedium parviflorum var. *makasin*	3	2016	SC	numerous
Cypripedium parviflorum var. *pubescens*	1	2016	N	numerous
Cypripedium reginae	2	2016	N	two locations
Dryopteris fragrans	1	2015	N	rock outcropping
Eriophorum chamissonis	1	2017	SC	hundreds of plants in one bog
Epilobium palustre	1	2017	SC	one plant
Gentiana alba	1	2017	N	several plants on riverbank
Geum macrophyllum var. *macrophyllum*	1	2016	SC	one plant
Huperzia selago	1	1996	SC	
Lactuca hirsuta	1	2015	N	a few dozen
Platanthera huronensis	1	2015	N	
Pyrola minor	1	2015	END	unknown
Petasites frigidus var. *sagittatus*	3	2015	THR	several populations
Rhynchospora fusca	1	2016	SC	hundreds of plants
Ribes oxyacanthoides	1	2017	THR	several plants
Taxus canadensis	3	2015	N	several plants
Tephroseris palustris	1	1897	SC	
Vaccinium vitis-idaea	1	2015	END	70–100 plants

and the large percentage of trees that were found at the seedling stage; these seedlings may have been discounted or overlooked by Thomson.

We observed 124 non-native species throughout all the forest communities we surveyed. Of these, *Rhamnus cathartica* poses the greatest threat to the lower reaches of the boreal forest, growing in thickets that replace native understory shrubs and forbs. *Iris pseudacorus* is found from the southern edge of Big Lake to the mouth of the river. There is an active invasive plant management program on Lake Minnesuing, and to a lesser extent on Lake Nebagamon, for controlling these populations, while the Brule River community is just becoming aware of the threat. *Myosotis scorpioides* and *Nasturtium officinale* are naturalized from near the headwaters to the mouth of the river and have likely replaced some native aquatic plant populations (e.g., *Ranunculus aquatilis*, *Callitriche palustris*, and *Callitriche hermaphroditica*). *Bromus inermis*, *Phalaris arundinacea*, and *Centaurea stoebe* are found growing along disturbed road, trails, ditches, parking

areas, and other disturbed areas, but the populations are well managed. Two emerging invasive plant threats to the watershed include the recent appearance of small populations of *Sorbus sorbifolia* and *Valeriana officinalis* that were found embedded in both the boreal forest and the northern wet-mesic forest. Lastly, a private landowner informed us of a large population of *Berberis thunbergii* planted decades earlier within the watershed, but our survey teams did not observe this species, and as a result it is not included on our list in Appendix 1.

Boreal Forest

By the time of the Thomson survey, the boreal forest was greatly diminished due to cutover with early successional species such as *Abies balsamea* and large stands of *Populus* spp. present. Boreal forest occupied approximately 6.9% of the watershed (Fassett 1944). Dominant species were *Betula papyrifera*, *Populus grandidentata*, *Populus tremuloides, and Prunus pensylvanica.* Ground cover species of importance were *Eurybia macrophylla*, *Diervilla lonicera* and *Pteridium aquilinum* (Thomson 1945).

The present-day boreal forest covers 3.6% (1,877 ha) of the watershed and is found north of the Copper Range. It is characterized as gradually sloping to the northeast within a gentle terrain, bisected by numerous steep ravines. A contiguous second- and third-growth aspen forest continues to dominate the forest today with some *Abies balsamea* and *Picea glauca* in the understory (Wisconsin Department of Natural Resources 2016b). Other areas have lost timber due to an alteration of the hydrology caused by heavy equipment resulting in swamping that favors thickets of *Alnus incana* and *Salix* spp.

Boreal forest *Ct* values indicate a slight decrease in floristic quality. Thomson did not discover as many non-native plants in these early successional forests (only 5%) as we did in today's boreal forest (14.9%). Thomson classified the boreal forest as "The Aspen Association," since the boreal forest composition was greatly compromised from early logging activities and was dominated by hardwoods in the 1940s (Fassett 1944, Thomson 1945). Family dominance has changed from Rosaceae, Asteraceae, Ranunculaceae, and Salicaceae in the 1940s to Cyperaceae, Asteraceae, Rosaceae, Poaceae, and Ranunculaceae today. The graminoids represent almost 20% of the boreal forest flora today, in contrast to only 7% in the 1940s. Many earlier inventories often overlooked graminoid species and that may explain the changes we observed. Another observation is that insect pollination dependent families (e.g., Rosaceae and Ranunculaceae) have declined, while wind-pollinated families (e.g., Cyperaceae and Poaceae) have substantially increased. These findings are consistent with the trends found during a project that re-surveyed the 1959 baseline data collected by John T. Curtis for selected northern forests in Wisconsin (Rooney et al. 2004).

The best examples of remnant boreal forest stands are along steep ravines near the mouth of the river and extending inland for several miles. The cooler climate and red clay soils dictate which tree species can be sustained in this part of the watershed. In these areas we see the returning prominence of *Pinus strobus*, *Abies balsamea*, and *Picea glauca*, while *Betula papyrifera* has decreased in abundance (Hlina et. al. 2018a). In the deep creek ravines along tributaries, dom-

inant trees include *Thuja occidentalis*, *Abies balsamea*, *Picea glauca*, and *Populus tremuloides*. The boreal forest on the Brule River is slowly recovering, and opportunities for restoration are high. In the Biotic Inventory of the Brule River State Forest O'Conner (2016) states:

> The Brule River State Forest offers the single best opportunity for clay plain boreal forest restoration on state-owned land on the entire Superior Coastal Plan Ecological Landscape and possibly North America.

Such restoration will ensure the continued biodiversity, complexity, and health of this rare plant community in Wisconsin for future generations.

Northern Wet-Mesic Forest

As noted earlier, Thomson (1945) lumped northern wet forest and northern wet-mesic forest into one plant community type, which he called conifer bog. The dominant species he noted were *Abies balsamea*, *Larix laricina*, *Picea mariana*, *Thuja occidentalis*, and *Sphagnum* spp. He noted two shrubs, *Chamaedaphne calyculata* and *Rhododendron groenlandicum*, as significant components of the understory. The coverage of this forest was 6.8% during his survey (Fassett 1944).

In the present day, northern wet-mesic forest encompasses 967 ha, approximately 2% of the watershed in the headwater region of the Brule River and is dominated by old-growth even-aged stands of *Thuja occidentalis*. From 1942 to 1945, Thomson observed that area residents and farmers were harvesting the cedar in this area for fence posts and other uses, exposing the sphagnum hummocks and pools to wind and sun resulting in severe desiccation and recommended that all cutting cease (Thomson 1945). Thomson recognized the importance of this area and the direct influence it had on sustaining water quality, water flow, and stable temperatures needed to support brown, brook, and rainbow trout populations in the river. This forest is now approaching 200 years of age and exhibits little apparent regeneration in the last 70–80 years. Beals et al. (1960) and others (Alverson et al. 1988; Van Deelen 1999; Rooney et al. 2002; Forester et al. 2008) have documented the impact of deer populations on the ability of *Thuja occidentalis* to regenerate. Due to the lack of regeneration, the *Thuja occidentalis* swamps, which are the largest in the state, are vulnerable to disappearance in the next 50–75 years (Bushman 2006; Scheller and Mlandenoff 2005, 2008). Based on our survey data and observations, this forest is most likely to be replaced by *Abies balsamea* and *Acer rubrum* trees with large patches of *Alnus incana* thickets.

Northern wet-mesic forest *Ct* values depict a decrease in floristic quality from 6.9 to 5.8 and in *Cn* values from 7 to 6.1. Non-native species slightly increased temporally, from 3% to 4.3%, but this alone does not explain the discrepancy in floristic quality between the two time periods. As was standard in the 1940s, and as noted earlier, Thomson classified both the northern wet forest (*Picea mariana* and *Larix laricina* dominant) and northern wet-mesic forest (*Thuja occidentalis* dominant) as one community type called conifer bog, though the former has a greater percentage of conservation species. In *Vegetation of Wisconsin*, Curtis

(1959) compares these two-forest community types and finds only a 50% similarity between them, and therefore separated them into northern wet forest and northern wet-mesic forest. This difference perhaps explains the wide differences in *C* values. Family dominance has also changed from Cyperaceae, Orchidaceae, Caprifoliaceae, Rosaceae, and Ericaceae to Cyperaceae, Asteraceae, Rosaceae, Poaceae, and Ericaceae. Graminoid dominance has increased from 11% to 17%. Surprisingly *Maianthemum canadense*, *Aralia nudicaulis*, and *Acer spicatum*, which are highly prevalent today, were not recorded in the 1940s. It is possible that these species were simply overlooked. Another substantial decline was found in Orchidaceae, dropping from 6.0% to 2.9%. Three orchid species that were present in the 1940s but are absent today are *Calopogon tuberosus*, *Goodyera pubescens*, and *Spiranthes cernua. Calypso bulbosa*, a state threatened orchid, is probably near extinction in the Brule River watershed (E. J. Judziewicz, personal communication 2016). Judziewicz studied the same cedar swamps in the mid- to late 1990s and found hundreds of individuals of *Calypso bulbosa* (Epstein et. al. 1999). During the field seasons of 2015 and 2016 only four plants were found, two of which were sterile and two in flower. Moreover, Rooney and Waller (2003) and Rawinski (2008) described the effects of high deer densities on the understory flora of forested ecosystems, which may explain some of this decline, as well as a drop in the C_t values of northern wet-mesic forest.

Pine Barrens

Pine barrens were frequently burned and were mostly treeless at the time of the Brule River surveys of the 1940s; the last big fire occurred in 1936 (Fassett 1944). Thomson (1945) and Fassett (1944) documented a much more intact pine barrens than we find today, noting many characteristics such as shrubby jack pine, scattered red pine savannas, and vast open barrens. They reported the pine barrens covered 25.7% of the total watershed in 1938; today pine barrens cover approximately 1.8% (908 ha). Lost to history is the full extent of the flora of the pine barrens as it existed in 1854. The land that was historically pine barrens is now managed as pine plantation monocultures predominantly by private timber companies, the Brule River State Forest, and Douglas and Bayfield counties. The *C*-values show little difference between the 1940s and now and may indicate that the pine barrens remain a community in recovery.

Thomson's (1945) description of the *Pinus banksiana* community distinguished between two paths of succession, both essentially leading to a *Pinus banksiana*, *P. resinosa*, *Quercus* spp. community based upon the intensity and intervening time between fires. He noted the dominant woody plants in scattered stands as *Pinus banksiana* and *Quercus ellipsoidalis.* Ground cover species of importance were *Corylus americana*, *Danthonia spicata*, *Comptonia peregrina, Pteridium aquilinum*, *Quercus macrocarpa*, *Salix humilis*, and *Vaccinium angustifolium.* (Thomson 1945). Many associate species are prairie species adapted to drier conditions, low soil fertility, and fire.

Pine barrens *Ct* and *Cn* values show little change between the two time periods. These values are low relative to other forest types and may indicate an overabundance of species tolerant of anthropogenic disturbances with low *C* values

in Asteraceae and Poaceae. These species accounted for more than 30% of the flora. Pine barrens of today are embedded in large acreages of pine plantation, resulting in the highest percentage of non-native species (16.4%) of all the communities surveyed. Family dominance has remained the same (Asteraceae, Poaceae, and Rosaceae). *Hieracium aurantiacum* (orange hawkweed) is the only non-native species that ranked high enough to make the prevalent ground layer species list for any community in the Brule River watershed. Another interesting observation is the successful spread of *Carex pensylvanica*, a native sedge that was not recorded by Thomson, though its presence in other adjacent forested communities may explain its presence in the pine barrens.

Due to the smaller open areas and savanna-like conditions, the globally rare pine barrens are home to a wide variety of wind-dispersed non-native plants (e.g., *Agrostis gigantea*, *Centaurea stoebe*, and *Cirsium arvense*). Fire suppression activities have altered the pine barrens landscape by eliminating large patches (950–1500 ac) of open habitat (Radeloff et.al. 2000; Grossman and Mladenoff 2007; Scheller and Mladenoff 2008). It is doubtful that the historical shifting mosaic of oak and pine savanna surrounded by large open patches will be achieved without further use of fire and other management tools by land managers. Open barrens in the watershed occur only in small parcels today, and not as the vast terrain of yesteryear, that numerous wildlife species such as sharp-tailed grouse, bobolink, and savannah sparrow require (Radeloff et al.1999). The best remaining examples of pine barrens in the Brule River watershed are found at Mott's Ravine State Natural Area and in patches between forests of recent harvests. It was at Mott's Ravine that *Lactuca hirsuta* was found, only the second collection of this species for Wisconsin. The 2003 Brule River State Master Plan includes plans to modestly increase the acreage of pine barrens found at Mott's Ravine (Van Horn et al. 2003).

Northern Dry Forest

Northern dry forest prior to extensive landscape disturbance was comprised of large stands of *Pinus resinosa* interspersed within pine barrens. The forest covered approximately 12% of the watershed. It was quickly harvested during the lumbering activities in the late 19th century and converted to jack and red pine plantations by the late 1930s. The five stands we surveyed were either *Pinus resinosa* plantations greater than 100 years old or small pockets of older *P. resinosa* and *P. banksiana* intermixed with scrub oak (*Quercus macrocarpa* and *Q. ellipsoidalis*). In the barrens area of the watershed, these forest plantations are heavily represented and occupy 28.5% (14,614 ha) of the watershed. Thomson treated this forest as a successional stage within the pine barrens complex and hence one-to-one comparison was not possible with our data. This forest, as expected, had one of the lowest diversities of all the communities and a higher level of non-native species compared to the other communities. The understory of the northern dry forest is dominated by *Acer rubrum* and *Abies balsamea* saplings and hazelnut (*Corylus* spp.), with pine regeneration not apparent. The Brule River State Forest has identified three primary sites for northern dry forest needing protection (Wisconsin Department of Natural Resources 2017). These sites

are exceptionally small and subject to catastrophic damage from extreme weather events. Opportunities for management, including the use of fire to increase open conditions for pine seedlings, are suggested in the 2016 Biotic Inventory of the Brule River State Forest (O'Connor 2016).

Northern Dry-Mesic Forest

At time of settlement these valuable northern dry-mesic forests encompassed 7.8% of the watershed and by the 1940's had declined to 1.8% of the area. Today, this forest type has slightly rebounded and occupies approximately 2.6% (1,325 ha) of the watershed, with most old growth northern dry-mesic forest in land trust stewardship. Due to generations of human activity with the creation of trails, roads, homes, outbuildings, and earlier landscape plantings, a suite of non-native species was found. Except for *Berberis thunbergii*, none of these species have compromised the ecological integrity of this old growth forest. *Berberis thunbergii*, which was planted in the area as an ornamental, has increased its spread in recent years into the surrounding forest. Species richness remains high (263 species), but much of the gain compared with Thomson's survey has come from non-native species (12.9% of the current total). *Acer rubrum* and *Abies balsamea* seedlings are dominant in the understory and are poised to become the replacement forest in the absence of *Pinus strobus* and *P. resinosa* regeneration. Though floristic richness remains high, 40% of species in this forest were found only once during the surveys of this forest type and at a relatively low abundance.

Northern Hardwood Swamp

Fassett (1944) and Thomson (1945) defined northern hardwood swamp as a lowland hardwood association, a minor component of the watershed, occupying only 6.7% of the total watershed area. Thomson (1945) noted that the dominant tree species are *Acer rubrum*, *Fraxinus nigra*, and *Ulmus americana.* Associated woody species included: *Abies balsamea*, *Alnus incana*, *Betula papyrifera*, and *Populus balsamifera*. Ground cover species were numerous and many of the species commonly associated with wet habitats, such as *Carex tuckermanii*, *Carex crinita*, *Scutellaria lateriflora*, *Galium trifidum*, and *Micranthes pensylvanica* were observed. Surprisingly, only 25% of prevalent ground layer species were common to both surveys. The discrepancy might be explained through the diversity of plant associations we observed in the thirteen northern hardwood swamp sites surveyed by our team.

Today, a large area of high-quality northern hardwood swamp exists in the watershed covering 10% (5,420 ha) of the watershed. The present-day northern hardwood swamp community has 307 species, of which 10.7% are non-native, which is in the lower range among the communities surveyed. This community harbored the greatest number of *Carex* species (32), as well as large numbers of shade tolerant specialists. By far the greatest threat to these lowland swamps is the invasion of the emerald ash borer that causes high mortality in all species of *Fraxinus*. Our survey did not find any evidence of the beetles. Likewise, no signs

of the beetle have ever been found in the Brule River State Forest (D. Schulz, personal communication 2017).

Based on our survey results, it is likely that these lowlands, if compromised by the beetle, may be replaced by *Acer rubrum*, *Abies balsamea*, and the shrub *Alnus incana*, as these species are the most well-represented woody species in understory layers. This could have a profound effect on the structure, function, and ecological integrity of this forest.

If *Fraxinus nigra* suffers increased mortality from an emerald ash borer invasion, it is likely that severe hydrological changes will occur in this wetland forest. Slesak et al. (2014) showed that in an infected ash forest, flood conditions lasted six to eight weeks longer, which would have serious consequences to the establishment of other tree species and the groundcover vegetation that grows based on hydrological regimes (saturation, very wet, wet, and moderately wet). In the Brule River region, these new conditions may favor weedy aquatic and wet meadow graminoid species, such as *Phalaris arundinacea*, *Typha* spp., and *Phragmites australis* that are able to easily colonize from adjacent landscapes. Some long-term projects evaluating the success of anticipated replacement species (e.g., *Quercus bicolor*, *Celtis occidentalis*) have been conducted or are underway in similar regional forests (Looney et al. 2015, Rooney et al. 2015). These two species remain south of the tension zone in Wisconsin and still have no presence in the Brule watershed.

Northern Mesic Forest

Fassett's (1944) land cover analysis depicted this forest type as having little importance in the watershed, with less than 1.7% of the land cover. Northern mesic forest stands were predominately located on the north side of Lake Minnesuing and to the east of the Brule River near and on the Copper Range and are known locally as Sugar Camp Hill. Dominant tree species included *Acer rubrum*, *Acer saccharum*, *Betula alleghaniensis*, *Betula papyrifera*, *Ostrya virginiana*, *Pinus strobus*, and *Tilia americana* (Thomson 1945). The associated ground cover species consisted of species associated with maple–basswood forest, such as *Dryopteris carthusiana*, *Actaea pachypoda*, *Botrypus virginianus*, *Sanicula marilandica*, and *Lysimachia ciliata*.

Thomson (1945) noted that the large sugar bush trees (*Acer* spp.) were gone, as was the sugar camp of earlier days. The topsoil was lost, first by logging and then with subsequent fires resulting in erosion. Most of the landscape of the 1940s was covered with a coppice scrubby growth of *Acer* spp., and Thomson predicted it would be many years before this forest recovered (Thomson 1945). Surprisingly, Thomson did not include *Tsuga canadensis* in his description of this forest. However, on May 9, 1944, Thomson did collect a voucher specimen on the bank of a stream crossing the Copper Range (Appendix 1). Later, Davidson et al. (1973) documented a range extension for *Tsuga canadensis* at one of the stands at the westernmost boundary of the watershed near Lake Minnesuing. Today, *Tsuga canadensis* is known to extend further west into St. Louis County in Minnesota and several others.

Today, northern mesic forest, typically dominated by *Acer saccharum*, *Betula*

alleghaniensis, and *Tilia americana*, comprises 1.5% of the watershed, covering 750 ha. As in yesteryear, this mesic forest is located along the Copper Range and on the southwestern side of Lake Minnesuing. Sugar Camp Hill on top of the Copper Range was last logged in 1933 and has slowly been regenerating a maple–basswood forest. Today, these stands have moved to a later successional stage and are slated to be harvested in the next decade. In the Lake Minnesuing area, some mesic forest stands have a component of *Tsuga canadensis*. These are privately and publicly owned, and most are of poor quality. A few are represented by multi-age stands with relatively high species diversity. A patch of *Adiantum pedatum* was found in a deep gully in such a stand and represents only the third known occurrence of this species in the watershed.

Northern Wet Forest

Thomson (1945) lumped this forest community type together with northern wet-mesic forest community type into what he called conifer bog. This is described in more detail above under northern wet-mesic forest.

Today, northern wet forest encompasses 3.8% (1,896 ha) of the watershed and consists of weakly minerotrophic, conifer-dominated, acid peatlands located north and south of the Lake Nebagamon region where the water table is near the surface or where drainage is somewhat impeded. A large forested complex consisting of a mix of *Fraxinus americana*, *Thuja occidentalis*, *Larix laricina*, and *Picea mariana* intergrade into a mosaic in this region, with species individually responding to gradients of pH, water depth, the presence of *Sphagnum* spp., and available nutrients. This forest is uncommon in the watershed, except in the headwaters region and is distinct with a specialized associations of plant species. However, even this forest has increased from zero non-native species to 6.4% between the two studies. An area deserving further protection occurs along the east side of Degerman Road, north of Lake Nebagamon. In this region we observed a northern wet forest dominated by a canopy of *Picea mariana* with ample regeneration of 3.6–4.6 m tall *Thuja occidentalis* and uncommon forbs underneath; this is the only area in the watershed known to have significant *Thuja occidentalis* regeneration.

CONCLUSION

Overall, our study has shown that the Brule River watershed is of exceptional quality, but also an area at high risk. Many challenges exist for sustaining, maintaining, and restoring its natural forest communities. The boreal forest remains susceptible to severe erosion of clay banks as rain events and snow melts intensify under changing climate scenarios. The northern wet-mesic swamps are even-aged and apparently not regenerating naturally. Northern hardwood swamps are likely to decline substantially in the watershed over the next 50 years from emerald ash borer infestations. Old growth northern dry-mesic forest will not likely regenerate in the absence of fires and are a declining presence in the watershed

forests. The pine barrens mosaic remains diminished and the area continues to be dominated by *Pinus resinosa* and *P. banksiana* plantations with only small opportunities to expand.

The purpose of this study was to document the existing flora, make comparisons with earlier surveys, and make qualitative and quantitative data available for future researchers. We highly recommend that a similar survey be made one or two decades after this study to document changes and inform land managers and decision-makers with new information for making the difficult decisions they will face in the future.

ACKNOWLEDGMENTS

The following organizations, agencies and individuals assisted in financially supporting the project, and we are forever grateful.

Grants: University of Wisconsin Foundation–Dr. Donald Davidson Memorial Fund; Enbridge EcoFootprint Grant; Wisconsin Coastal Management Grant Program (grant no. NA15NOS4190094).

Organizations: Brule River Coalition, Brule River Preservation, Brule River Sportsman's Club, Friends of the Brule River, Winneboujou Club, The Nature Conservancy, Cedar Island Conservancy, Douglas County Land and Water Conservation Department, West Wisconsin Land Trust, Wisconsin Department of Natural Resources (Brule River State Forest, State Natural Areas Program, Bureau of Natural Heritage Conservation).

We extend our deepest appreciation to Dr. Michael Huft, editor of the Great Lakes Botanist and the anonymous reviewer for adding insight, extensive notes and suggestion for both conciseness and clarification for this article and its companion article, "Analyzing Vegetative Cover of the Bois Brule River Watershed Re-Visited in Northwestern Wisconsin, Part I: Forest Stand Changes (1968 to 2016)."

We honor the memories of Dr. John W. Thomson, Jr., and Dr. Donald W. Davidson and hope we've done justice in interpreting their data and work, as without this data, none of this work would have been possible. We were honored and grateful to have the expertise of Dr. Loy Richard Phillippe of the Illinois Natural History Survey, whose more than 44,000 collections in his extraordinary career provided specimen details we often didn't know or see. We also are deeply grateful to Dr. Emmet Judziewicz, professor emeritus, University of Wisconsin-Stevens Point. Emmet was always our lead botanist finding the unusual or a niche upon a niche finding that obscure plant. I still don't know how he sighted *Carex ×knieskernii* among the *Carex arctata* and *Carex castanea* in an upland white cedar swamp. Thank you, Emmet!

Thank you to Dr. Matt Tenyck for his comments on earlier drafts of this article and his unending support for numerous requests. We are thankful to Dr. Brenda Molano-Flores and Ms. Jean Mengelkoch for their assistance with preparing plant specimens for the project. We also want to thank UW-Superior alumni and students who worked on this project—Stephanie Glass, Research Tech 1, and UW-Superior natural science students Paige Kent, Mike Krick, Adam Krick, Daniel Gil De La Madrid, and Molly Bergman for working a lot of extra hours to ensure the quality of the reported data and meeting every unreasonable demand we asked of them and then some. You have all been so awesome, generous, and kind, and it has been a privilege and an honor to learn from you, guide you, and share with you the diversity of one of the most pristine landscapes in Wisconsin. Let our paths cross again in the wild places on the Brule.

LITERATURE CITED

Alverson, W. S., D. M. Waller, and S. L. Solheim. (1988). Forests too deer: Edge effects in northern Wisconsin. Conservation Biology 2: 348–358.

Beals, E. W., G. Cottam, and R. J. Vogl. (1960). Influence of deer on vegetation of the Apostle Islands, Wisconsin. The Journal of Wildlife Management 24: 68–80.

Bean, E. F., and J. W. Thomson, Jr. (1944). Topography and geology of the Brule River Basin. Brule

River Survey: Paper no. 2. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 35: 7–17.

Bernthal, T. W. (2003). Development of a floristic quality assessment methodology for Wisconsin. Wisconsin Department of Natural Resources, Madison.

Burton, J. I., D. J. Mladenoff, J. A. Forrester, and M. K. Clayton. (2014). Experimentally linking disturbance, resources and productivity to diversity in forest ground-layer plan communities. Journal of Ecology 102: 1634–1648.

Bushman, M. M. (2006). Plant species change in northern Wisconsin wet-mesic forest communities from 1952 to 2005. A research paper submitted in partial fulfillment of the requirements of the degree of Master of Science, College of Natural Resources, University of Wisconsin-Stevens Point.

Churchill, W. S. (1945). The brook lamprey in the Brule River. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Brule River Survey: Paper no. 10. 37: 337–46.

Clayton, L. (1984). Pleistocene geology of the Superior Region, Wisconsin. Information Circular 46. Wisconsin Geological and Natural History Survey, Madison.

Consortium of Midwest Herbaria. (2020). Brule River State Forest Surveys. Available at http://midwestherbaria.org/portal/checklists/checklist.php?clid=5941&emode=1.

Curtis, J. T. (1959). The vegetation of Wisconsin: An ordination of plant communities. The University of Wisconsin Press, Madison.

Davidson, D. W., R. A. Ahlberg, R. G. Koch, and D. J. Lahti (1973). A westward extension of hemlock in Wisconsin. The Michigan Botanist 12: 209–211.

Dott, R. H., Jr. and J. W. Attig. (2004). Roadside Geology of Wisconsin. Mountain Press Publishing Company, Missoula, Montana.

Epstein, E., W. Smith, J. Dobberpuhl, and A. Gavin. (1999). Biotic inventory and analysis of the Brule River State Forest: A baseline inventory (1995–97) and analysis of natural communities, rare plants and animals, aquatic invertebrates, and other selected features in preparation for State Forest Master Planning. Wisconsin's Natural Heritage Inventory Program. Madison.

Epstein, E.E. (2017). Natural communities, aquatic features, and selected habitats of Wisconsin. Chapter 7 in: The ecological landscapes of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management. Wisconsin Department of Natural Resources, PUBSS-1131H 2017, Madison.

Evans, R. (1945). Bottom deposits of the Brule River. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Brule River Survey: Paper no. 9. 37: 325–35.

Fassett, N. C. (1944). Vegetation of the Brule basin, past and present. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Brule River Survey: Paper no. 4. 37: 33–56.

Fischthal, J. H. (1945). Parasites of Brule River fishes. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Brule River Survey: Paper no. 6. 37: 275–78.

Flora of North America Editorial Committee, editors. (1993+). Flora of North America North of Mexico. 20+ vols. Oxford University Press, New York, N.Y.

Forester, J. D., D. P. Anderson, and M. G.Turner. (2008). Landscape and local factors affecting northern white cedar (*Thuja occidentalis*) recruitment in the Chequamegon-Nicolet National Forest, Wisconsin, USA. The American Midland Naturalist 160: 438–353.

Grossman, E. B., and D. J. Mladenoff. (2007). Woodland and savanna decline in mixed-disturbance landscape (1938 to 1998) in the northwest Wisconsin (USA) sand plain. Landscape Ecology 22: 43–45.

Hlina, P. S., R. J. Schwarting, and N. P. Danz. (2018a). Floristic quality assessment of wetlands of the Brule River watershed. Technical Report 2018-2, Lake Superior Research Institute, University of Wisconsin-Superior, Superior, Wisconsin.

Hlina, P. S., R. J. Schwarting, M. A. Feist, and D. S. Anderson. (2018b). Analysis of the vegetative cover of the Brule River watershed revisited: 1852–2017. Technical Report 2018-3, Lake Superior Research Institute, University of Wisconsin, Superior, Wisconsin.

Hlina, P. S., D. S. Anderson, R. J. Schwarting, and M. A. Feist. (2020). Analyzing vegetative cover of the Bois Brule River watershed re-visited in northwestern Wisconsin, Part I: Forest stand changes (1968 to 2016). The Great Lakes Botanist 59: 1–23.

Judziewicz, E. J., R. W. Freckmann, L. G. Clark, and M. R. Black. (2014). Field guide to Wisconsin Grasses. The University of Wisconsin Press, Madison.

LaBerge, G. L. (1994). Geology of the Lake Superior region. Penokean Press, Oshkosh, Wisconsin.

Looney, C. E., A. W. D'Amato, B. J. Palik, and R. A. Slesak. (2015). Overstory treatment and plant-

ing season affect survival of replacement tree species in emerald ash borer threatened *Fraxinus nigra* forests in Minnesota, USA. Canadian Journal of Forest Research 45: 1728–1738.
Matthews, J. W., P. A. Tessene, S. M. Wiesbrook, and B.W. Zercher. 2005. Effect of area on isolation on species richness and indices of floristic quality in Illinois, USA wetlands. Wetlands 25:607–615.
Midwestern Regional Climate Center. (2017a). Precipitation data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_pcpn.jsp?stnId=USC00473186; Temperature data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_temp.jsp?stnId=USC00473186; Growing season data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_grow.jsp?stnId=USC00473186 (Accessed Nov 19, 2017).
Midwestern Regional Climate Center. (2017b). Precipitation data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_pcpn.jsp?stnId= USC00478349; Temperature data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_temp.jsp?stnId= USC00478349; Growing season data available at https://mrcc.illinois.edu/mw_climate/climateSummaries/climSummOut_grow.jsp?stnId= USC00478349 (Accessed Nov 19, 2017).
O'Connor, R. (2016). Biotic inventory report for the Brule River State Forest: An updated inventory and analysis of rare plants and animals and high-quality natural communities in support of a Master Plan update. PUB-NH-856 2016 Wisconsin's Natural Heritage Inventory Program, Madison.
O'Donnell, D. J. (1944). A history of fishing in the Brule River. Brule River Survey: Paper no. 3. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 36: 19–31.
O'Donnell, D. J. (1945). A four-year creel census on the Brule River, Douglas County, Wisconsin. Brule River Survey: Paper no. 7. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 37: 279–303.
O'Donnell, D. J., and W. S. Churchill. (1954). Certain physical, chemical and biological aspects of the Brule River, Douglas County. Brule River Survey: Paper no. 11. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 43: 201–45.
Radeloff, V. C., D. J. Mladenoff, H. S. He, and M. S. Boyce. (1999). Forest landscape change in the northwestern Wisconsin pine barrens from pre-European settlement to the present. Canadian Journal of Forest Research 29: 1649–1659.
Radeloff, V. C., D. J. Mladenoff, and M. S. Boyce. (2000). A historical perspective and future outlook on landscape scale restoration in the northwest Wisconsin pine barrens. Restoration Ecology 8: 119–126.
Rawinski, T. J. (2008). Impacts of white-tailed deer overabundance in forest ecosystems: An overview. Northeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture, Newton Square, Pennsylvania.
Rooney, T. P., S. L. Solheim, and D. M. Waller. (2002). Factors affecting the regeneration of northern white cedar in lowland forests of the Upper Great Lakes region, USA. Forest Ecology and Management 163: 119–130.
Rooney, T. P., and D. M. Waller. (2003). Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181: 165–176.
Rooney, T. P., S. M. Wiegmann, D. A. Rogers, and D. M. Waller. (2004). Biotic impoverishment and homogenization in unfragmented forest understory. Conservation Biology 18: 787–798.
Rooney, T. P. (2009). High white-tailed deer densities benefit graminoids and contribute to biotic homogenization of forest ground-layer vegetation. Plant Ecology 202: 103–111.
Rooney, T. P., R. Buttenschon, P. Madsen, C. Olesen, A. A. Royo, and S. L. Stout. (2015). Integrating ungulate herbivory into forest landscape restoration. Pp. 69–84 in Restoration of boreal and temperate forests. Second edition, J. A. Stanturf, editor. CRC Press, Boca Raton, Florida.
Scheller, R. M., and D. J. Mladenoff. (2005). A spatially interactive simulation of the effects of climate change, harvesting, wind, and tree species migration on the forest composition and biomass in northern Wisconsin, USA. Global Change Biology 11: 307–321.
Scheller, R. M., and D. J. Mladenoff. (2008). Simulated effects of climate change, fragmentation, and inter-specific competition on tree species migration in northern Wisconsin, USA. Climate Research 36: 191-202.
Schneberger, E., and A. D. Hasler (1944). Brule River Survey: Introduction. Brule River Survey: Paper no. 1. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 36: 1–5.

Schwarting, R. S., P. S. Hlina, and N. P. Danz. (2018). 2017 floristic quality assessment of littoral plant communities in Lake Minnesuing and Lake Nebagamon, Douglas County, Wisconsin. Technical Report 2018-1, Lake Superior Research Institute, University of Wisconsin- Superior, Superior, Wisconsin.

Slesak, R. A., C. F. Lenhart, K. N. Brooks, A. W. D'Amato, and B. J. Palik. (2014). Water table response to harvesting and simulated emerald ash borer mortality in black ash wetlands in Minnesota, USA. Canadian Journal of Forest Research 44: 961–968.

Sørensen, T. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analysis of the vegetation on Danish commons. Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter 4: 1–34.

Sweet, E. T. (1880). Geology of the western Lake Superior district. Geology of Wisconsin 3: 321–322.

Swink, F., and G. Wilhelm. (1979). A method for environmental assessment of open land. Pages 850–861 in Plants of the Chicago region. The Morton Arboretum, Lisle, Illinois, USA.

Spyreas, G. (2019). Floristic quality assessment: a critique, a defense, and a primer. Ecosphere 10(8): e02825.10.1002/ecs2.2825.

Thomson, J. W. Jr. (1944). A survey of the larger aquatic plants and bank flora of the Brule River. Brule River Survey: Paper no. 5. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 35: 57–76.

Thomson, J. W. Jr. (1945). An analysis of the vegetative cover of the Brule River (Wisconsin) watershed. Brule River Survey: Paper No.8. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 37: 305–323.

U.S. Environmental Protection Agency (1980). Red clay project: Impact of nonpoint pollution control on western Lake Superior. Final Summary Report (EPA 905/9-79-002, January 1979), Final Part II (EPA 905/9-79-002-B), and Final Part III (EPA 905/9-79-002-C).

Van Deelen, T. R. (1999). Deer-cedar interactions during a period of mild winters: Implications for conservation of conifer swamp deer yards in the Great Lakes region. Natural Areas 19: 263–274.

Van Horn, K., K. Brokaw, and S. Peterson. (2003). Brule River master plan and environmental impact statement. Wisconsin Department of Natural Resources, Publication PUB-FR-225.

Voss, E. G., and A. A. Reznicek. (2012). Field manual of Michigan flora, The University of Michigan Press, Ann Arbor.

Wilhelm, G. S. (1977). Ecological assessment of open land areas in Kane County, Illinois: A checklist of the Kane County flora with numerical evaluations—its basis, rationale and application. Kane County Urban Development Division, Geneva, Illinois.

Wisconsin Department of Natural Resources. (2016a) Wiscland 2.0. Land Cover Data [Raster File]. Wisconsin Department of Natural Resources.

Wisconsin Department of Natural Resources. (2016b). Wisconsin forest inventory and reporting system. Brule River State Forest. Available at https://dnrxwisconsingov/wisfirs/external/wisfirsaspx (Accessed April 09 2016).

Wisconsin Department of Natural Resources (2016c). Wisconsin wetlands and tools for assessment. Available at https://dnr.wi.gov/topic/wetlands/methods.html (Accessed April 9, 2016).

Wisconsin Department of Natural Resources. (2016d). Wisconsin natural heritage working list. Available at https://dnr.wi.gov/topic/nhi/wlist.html. (Accessed November 23, 2016).

Wisconsin Department of Natural Resources. (2017). Brule River State Forest master plan. http://dnrwigov/topic/Lands/MasterPlanning/Brule/.

APPENDIX 1. Vascular plant taxa documented for the Brule River Watershed. Nomenclature follows Voss and Reznicek (2012) for species known to occur in Michigan. Nomenclature for other species follows the published volumes of the Flora of North America (Flora of North America Editorial Committee 1993+) and Judziewicz et al. (2014) was used for grasses. The list is organized by major plant groups, then alphabetically by family and species within each major group. Non-native species are indicated by an asterisk (*) in front of the name.

For taxa collected during the current project, the collection number is prefaced by the initial of the last name of the primary collector: A = Anderson; F = Feist; H = Hlina; M = Marcum; P = Phillipe; S = Schwarting. Earlier collections are indicated by an italicized collection number and by the full name of the collector with the exception of Thomson, whose collections are denoted with a *T*. Links to the voucher specimens can be found at Consorium of Midwest Herbaria (2020).

The Habitat column indicates the most common communities in which a particular species was observed, using the following abbreviations: BF = Boreal Forest; WC = White Cedar; PB = Pine Barrens; NDF = Northern Dry Forest; NDMF = Northern Dry-Mesic Forest; NHS = Northern Hardwood Swamp; NMF = Northern Mesic Forest; BSS = Black Spruce/Tamarack Forest; AP = Aquatic Plants (Brule River, Lake Minnesuing, Lake Nebagamon); MB = Mud Bank Plants; W-NF = Wetlands - Non-forested; LSS = Lake Superior Shoreline; D = Disturbed Site.

The Status column indicates whether a taxon is on Wisconsin's rare species list (END = Endangered; THR = Threatened; SC = Special Concern), is a new record for the Brule River watershed (indicated by WS), or is a new county record (indicated by CR).

Taxon	Habitat	Status
PTERIDOPHYTES		
ATHYRIACEAE (LADY FERN FAMILY)		
Athyrium filix-femina (L.) Roth (common lady fern); F6037, F6074, F6411, F6489, M6844, M6882, F6489, T5159, T5525	BF, NDMF	
CYSTOPTERIDACEAE (Brittle Fern Family)		
Cystopteris fragilis (L.) Bernh. (brittle bladder fern); M7134, M7135, F5654	BG	WS
Cystopteris tenuis (Michx.) Desv. (MacKay's brittle fern); *Sommerville 95*	NMF	
Gymnocarpium dryopteris (L.) Newm. (common oak fern); F6008, F6093, M6863, *T5503*	BF, NMF	
DENNSTAEDTIACEAE (Bracken Fern Family)		
Pteridium aquilinum (L.) Kuhn (bracken fern); F6409, S109, *T5088*, *T5100*	PB, NDMF	
DRYOPTERIDACEAE (Wood Fern Family)		
Dryopteris carthusiana (Vill.) H. P. Fuchs (spinulose wood fern); F6002, F6005, F6092, F6360, M6974, M7056, M7138, M6845, M6862, *Ts.n.*	BF, NMF	
Dryopteris cristata (L.) A. Gray (crested shield fern); F6360, M6838, M6860, *T5507*	WC, NHS	
Dryopteris fragrans (L.) Schott (fragrant fern); F5658	BG	
Dryopteris intermedia (Willd.) A. Gray (evergreen wood fern); F6336, F5624, P43857	BF, NDM	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
EQUISETACEAE (Horsetail Family)		
Equisetum arvense L. (common horsetail); H3568	BF, NMF	
Equisetum fluviatile L. (river horsetail); F6579, H3635, H3789, M7295	BSS. AP	
Equisetum hyemale L. (scouring rush); H3985, H3565	NHS, NMF	
Equisetum laevigatum A. Braun (smooth horsetail); H3706	NMF	WS
Equisetum scirpoides Michx. (dwarf scouring rush); F5618, F5644, F6139, M6721	WC	
Equisetum sylvaticum L. (woodland horsetail); F5634, M6720, P43787	BF, NMF	
Equisetum ×ferrissii Clute (woodland horsetail); *T5549*	NDF	
ISOETACEAE (Quillwort Family)		
Isoetes echinospora Durieu (spiny spored quillwort); S233	AP	
LYCOPODIACEAE (Club-Moss Family)		
Dendrolycopodium dendroideum (Michx.) A. Haines (tree club moss); A2630, F6101, F6331, M6649, P43848, P44191	BF, NDMF	
Dendrolycopodium hickeyi (W.H. Wagner, Beitel & R.C. Moran) A. Haines (Hickey's tree club moss); H3874, H3979, M6849	WC, NDMF	WS
Dendrolycopodium obscurum (L.) A. Haines (ground pine); *Conklin 404, Salomaki 97/36*	WC	
Diphasiastrum complanatum (L.) Holub (northern ground-cedar); M6766	NDF, NDMF	WS
Diphasiastrum digitatum (Dill. ex A.Braun) Holub (trailing ground-pine); A2628, H3513, M7248, S113, S287	NDMF	
Diphasiastrum tristachyum (Dill.) Holub (northern ground-pine); M7211	PB	
Huperzia lucidula (Michx.) R.Trevis. (shining club moss); H3656, F5610, *Ts.n.*	WC, NHS	
Huperzia selago (L.) Bernhardi (fir club moss); *Clark 1065*	WC	
Lycopodiella inundata (L.) Holub (bog club moss); *T5360*	W-NF	
Lycopodium clavatum L. (running ground pine); F6332, H3518, M6650, M7212, P43866	NDF, NDMF	
Spinulum annotinum (L.) A. Haines (stiff clubmoss); F5615, F6100, F6328, M6651, M7114, M6866, P44105, *T5341, T5495*	WC, NDMF	
ONOCLEACEAE (Sensitive Fern Family)		
Matteuccia struthiopteris (L.) Todaro (ostrich fern); P43774, F6513, F6570, *Ts.n.*	NHS, NMF	
Onoclea sensibilis L. (sensitive fern); F6118, F6375, F6496, M6969, P43775, P44156, *Ts.n.*	BF, NHS	
OPHIOGLOSSACEAE (Adder's-Tongue Family)		
Botrychium lanceolatum (S.G.Gmel.) Angstr. (lace-leaved moonwort); *T5577*	NMF	
Botrypus virginianus (L.) Michx. (rattlesnake fern); S127, *T5391, T5559*	WC	
Sceptridium multifidum (S. G. Gmel.) M. Nishida (leathery grape fern); *T5400*	PB	

OSMUNDACEAE (Royal Fern Family)		
Osmunda claytoniana L. (interrupted fern); S120	BF, NMF	
Osmunda regalis L. (royal fern); S191	WC, NHS	
Osmundastrum cinnamomeum (L.) C. Presl (cinnamon fern); F6319, S110	WC, BSS	
POLYPODIACEAE (Polypody Fern Family)		
Polypodium virginianum L. (common polypody fern); F5645.1, M7119, *T5311*	BG	
PTERIDACEAE (Maidenhair Fern Family)		
Adiantum pedatum L. (maidenhair fern); S142	NMF	
SELAGINELLACEAE (Spikemoss Family)		
Selaginella rupestris (L.) Spring (rock spikemoss); F5651, *T5142, T5200*	PB	
THELYPTERIDACEAE (Marsh Fern Family)		
Phegopteris connectilis (L.) Slosson (northern beech fern); F6011, F6073 H3607, M6874, *T5504*	BF, NMF	
Thelypteris palustris Schott (marsh fern); S186, *T5528*	WC, NHS	
WOODSIACEAE (Woodsia Family)		
Woodsia ilvensis (L.) R. Br. (rusty cliff fern); F5646, F5650.1, *T5335*	BG	
GYMNOSPERMS		
CUPRESSACEAE (Cypress Family)		
Thuja occidentalis L. (white cedar); M7288, P44145, *Ts.n.*	WC, BF	
PINACEAE (Pine Family)		
Abies balsamea (L.) Mill. (balsam fir); S34, S45, H4288, *T499, T5500*	BF, WC, NDFM	
Larix laricina (Du Roi) K. Koch (tamarack); M7030, M7163, M7306, F6428, F6376, P44097, *T s.n.*	BSS, WC	
**Picea abies* (L.) H. Karst (Norway spruce); S86	BF	
Picea glauca (Moench) Voss (white spruce); S38, S46	BF, NDMF	WS
Picea mariana (Mill.) Britton, Sterns & Poggenb. (black spruce); F6404, M7262, M7309, *T5497*	BSS, WC	
Pinus banksiana Lamb. (jack pine); M6691, M6810, P44006, *T5223, T5698*	PB, NDMF	
Pinus resinosa Aiton (red pine); F5652	PB, NDMF	
Pinus strobus L. (white pine); P43779	NDMF, WC	
**Pinus sylvestris* L. (Scotch pine); S289	BF	
Tsuga canadensis (L.) Carrière (eastern hemlock); F6098, S119, T5501	NMF	WS

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
TAXACEAE (Yew Family)		
Taxus canadensis Marshall (American yew); H3418, P43784, *Ts.n.*	BF, WC	
DICOTS		
ADOXACEAE (Moschatel Family)		
Sambucus canadensis L. (American elderberry); H2397	WC, BSS	WS
Sambucus racemosa L. (red-berried elder); F5625, F6060, S69	BF, NMF	
Viburnum lentago L. (nanny berry); F6571, H3951, P43884, S133, *T5518*	BF, WC	
Viburnum rafinesquianum Schult. (arrow-wood); P43783, P44212, F6348, F6600	BF, NHS	WS
Viburnum trilobum Marshall (American high-bush cranberry); H3954, P44153, F6595, *T5477*	BF, WC	
AMARANTHACEAE (Amaranth Family)		
Chenopodium album L. (lamb's quarters); S278	PB	
Chenopodium simplex (Torr.) Raf. (maple leaf goosefoot); F6125	BF	WS
**Froelichia gracilis* (Hook.) Moq. (cottonweed); *Judziewicz 12125, Sumlan 737*	PB	
ANACARDIACEAE (Cashew Family)		
Rhus typhina L. (staghorn sumac); H4108, *T5257*	BF, NDF	
Rhus x pulvinata Greene (hybrid sumac); *T5500*	NMF	
Toxicodendron rydbergii (Rydb.) Greene (western poison-ivy); S129	NDF, NDMF	WS
APIACEAE (Parsley Family)		
Angelica atropurpurea L. (purple-stemmed angelica); S265	W-NF	
Cicuta bulbifera L. (bulblet water hemlock); H3910, M7242, M7281, F6523, *T5091*	W-NF, NHS	
Cicuta maculata L. (water hemlock); F6089, M6864, P44146	BF, NHS	
Heracleum maximum Bartram (cow parsnip); H4072, M6730, *T5540*	W-NF	
Osmorhiza claytonii (Michx.) C. B. Clarke (hairy sweet cicely); F6335, S128, *T5538*	NMF	
**Pastinaca sativa* L. (wild parsnip); *T5255*	D	
Sanicula marilandica L. (black snakeroot); F6079, M6765, M6808, M7003, *T5482*	BF, NMF	
Sanicula odorata (Raf.) Pryer & Phillippe (clustered black snakeroot); *Christensen s.n.*	BF	
Sium suave Walter (water parsnip); H3624, P44070, *T5320*	W-NF, NHS	
Zizia aurea (L.) W. D. J. Koch (common golden alexanders); P43867	BF	WS

APOCYNACEAE (Dogbane & Milkweed Family)		
Apocynum androsaemifolium L. (spreading dogbane); H4046, S205	PB, NDF	
Apocynum cannabinum L. var. *hypericifolium* A. Gray (clasping dogbane); S181	BF	WS
Asclepias exaltata L. (poke milkweed); H3511, H3616, M7216	NDMF, PB	WS
Asclepias incarnata L. (swamp milkweed); M7247, *T5290, T5547*	W-NF, NHS	
Asclepias ovalifolia Decne (dwarf milkweed); H3386, H3387	PB	THR, WS
Asclepias syriaca L. (common milkweed); H4044, S254	BF	
AQUIFOLIACEAE (Holly Family)		
Ilex mucronata (L.) M. Powell, V. Savolainen & S. Andrews (mountain holly); A2441, F6432, F6458, M6662, M6827, M7162, P44133, *T5482*	WC, BSS	
Ilex verticillata (L.) A. Gray (winterberry); F6061, F6146, F6432, M6823, M7181, M7289, P43868, P44160, P44185, P44208, *T5096*	BF, NMF, NHS	
ARALIACEAE (Ginseng Family)		
Aralia hispida Vent. (bristly sarsaparilla); *T5256*	NMF	
Aralia nudicaulis L. (wild sarsaparilla); F6308, F6407, P43746, *T5479*	BF, NDMF, NMF	
Aralia racemosa L. (American spikenard); F6407, M7126, P43860, *T5099, T5545*	BF, NDMF, NMF	
Hydrocotyle americana L. (marsh pennywort); H3556, M6842	WC	
Panax trifolius L. (dwarf ginseng); H3566, H3816, S194, *T5418*	NMF	WS
ARISTOLOCHIACEAE (Birthwort Family)		
Asarum canadense L. (Canadian wild-ginger); F5631, H3562, H3857, S103	WC, NDMF	
ASTERACEAE (Sunflower Family)		
Achillea millefolium L. (common yarrow); H3487, S170	PB, NDF	
**Achillea ptarmica* L. (sneezewort); *Gerst s.n.*	D	
Ambrosia artemisiifolia L. (ragweed); H4061	PB, NCF	WS
Ambrosia psilostachya DC. (western ragweed); *T s.n.*	NDMF	
Anaphalis margaritacea (L.) Benth. (pearly everlasting); H3962, M7231	PB, NDF	
Antennaria howellii Greene (small pussy's toes); F5657, M6696, P44035, P44043, *T5328, T5329, T5372, T5375*	PB, NDF	
Antennaria neglecta Greene (cat's foot); H3582, S95	BF	
Antennaria parlinii Fernald (smooth pussy's toes); M6693, P43760, P44022, *T5205, T5374*	PB, NDMF	
**Arctium minus* Bernh. (common burdock); S270	BF	WS
**Artemisia pontica* L. (Roman wormwood); *T5270*	PB	
**Artemisia vulgaris* L. (mugwort); *T5116*	NDMF	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Bidens beckii Spreng. (water beggar-ticks); F6515, *T5367*	AP	
Bidens cernua L. (nodding beggar's tick); F6553, M7278, *T5359*	W-NF	
Bidens connata Willd. (purple-stemmed tickseed); H3791	W-NF-NHS	
Bidens discoidea (Torr. & A. Gray) Britton (swamp beggar's tick); H3938	WC, NHS	CR
Bidens frondosa L. (common beggar's tick); F6138, F6555, M6848, M7240, P44139, *Ts.n.*	W-NF, NHS	
Bidens tripartita L. (straw-stem beggar-ticks); H3534	W-NF	
Bidens vulgata Greene (tall beggar-ticks); H3484	W-NF, NHS	WS
**Centaurea jacea* L. (brown knapweed); *T5076*	PB, NDF	
**Centaurea stoebe* L. (spotted knapweed); H4088, *T5190*	PB, NDF	
**Cirsium arvense* (L.) Scop. (Canada thistle); H3834, M7228	NDF, BF	
Cirsium discolor (Willd) Spreng. (field thistle); *Mitchell 87*	PB	
Cirsium muticum Michx. (swamp thistle); F6494, H3585, H3690, *Ts.n.*	NHS, BF	
**Cirsium vulgare* (Savi) Ten. (bull thistle); S264	PB, NDMF	
Conyza canadensis (L.) Cronq. (horseweed); M6778, P43898, *T5544*	PB	
**Crepis tectorum* L. (hawk's beard); *T5268*	PB	
Doellingeria umbellata (Mill.) Nees (flat-topped aster); F6080, M6832, M6885, P43869, P44136, P44178, *T5139, T5566*	BF, NMF	
Erechtites hieraciifolius (L.) DC. (burnweed); H3987	PB	
Erigeron annuus (L.) Pers. (annual fleabane); S193, S207	BF	WS
Erigeron glabellus Nutt. (streamside fleabane); S283, *T5548*	PB	
Erigeron strigosus Willd. (daisy fleabane); M6746, M6790, *T5182, T5387*	PB, NDMF	
Eupatorium perfoliatum L. (boneset); P44213, S274	W-NDF	
Eurybia macrophylla (L.) Cass. (big-leaved aster); F6072, P44167, *T5517*	BF, NDF	
Euthamia graminifolia (L.) Nutt. (grass-leaved goldenrod); H3725, P43906, *T s.n.*	PB, NDMF	
Eutrochium maculatum (L.) E. E. Lamont (spotted Joe-pye-weed); M6858, P44158, *T5298*	W-NF	
**Gnaphalium uliginosum* L. (cud weed); H3963, *T5195*	NDMF	
**Grindelia squarrosa* (Pursh) Dunal (gumweed); *T5434*	NMF	
Helianthus giganteus L. (giant sunflower); P43881, M7263, F6598, *T5449*	BF, NDMF	
Helianthus hirsutus Raf. (hairy sunflower); H3486	BF	CR
Helianthus occidentalis Riddell (western sunflower); M6745, M6785, *T5130*	PB	
Helianthus strumosus L. (pale-leaved sunflower); H3738, M6792	PB	
**Hieracium aurantiacum* L. (devil's paintbrush); F6361, M6788, M6999, P43897	PB, NDF, NDMF	WS
**Hieracium caespitosum* Dumort. (yellow hawkweed); M6743, M7000, P44004	PB, NDF	

**Hieracium lachenalii* Suter (common hawkweed); F6029, F6097, P43865	BF, NDMR	CR
**Hieracium piloselloides* Vill. (glaucous king-devil); H4095, S135	NHS, NMF	WS
Hieracium scabrum Michx. (rough hawkweed); P43891, P43907, M7111, S29, *T5483*	BF, PB	
Hieracium umbellatum L. (Canada hawkweed); F6076, M6793	PB, NMF	WS
Krigia biflora (Walter) S. F. Blake (false-dandelion); H3842, P44013	PB	CR
Lactuca biennis (Moench) Fernald (tall blue lettuce); S177	PB, NHS	WS
Lactuca canadensis L. (Canada lettuce); P43854, *T5186, T5187*	PB, NMF	
Lactuca hirsuta Nutt. (hairy tall lettuce); M6749	PB	WS
**Leucanthemum vulgare* Lam. (ox-eye daisy); S134, *T5543*	PB, NDF	
Liatris aspera Michx. (rough blazing star); M6781, M7226, P43904	PB	
Liatris ligulistylis (A.Nelson) K.Schum. (meadow blazing star); *T5071*	PB	
**Matricaria discoidea* DC (pineapple weed); S2111	D	
Packera aurea (L.) Á. Löve & D. Löve (golden ragwort); M6970, M6977, M7043, *T5559*	NDF, NHS	
Packera paupercula (Michx.) Á. Löve & D. Löve (northern ragwort); F6353, P44018, P44050, S173, *T5332, T5515*	PB, NHS	
Petasites frigidus (L.) Fries (sweet colt's-foot); H3555	BF, NDMF	
Petasites sagittatus (Pursh) A. Gray (arrowhead sweet colt's foot); Photo	BF	THR
Prenanthes alba L. (white lettuce); F6086, P44169, S21, *T5441*	BF, NMF	
Pseudognaphalium obtusifolium (L.) Hilliard & B. L. Burtt (cat's-foot; fragrant cudweed); F6087, M6794, P43919	PB, NDMF	CR
Rudbeckia hirta L. (black-eyed Susan); H4063, *T5388*	NDF	
Rudbeckia laciniata L. (cut-leaved coneflower); *T5523, T5524*	BF	
Solidago canadensis L. (Canada goldenrod); S280, *T5516*	BF, NMF	
Solidago flexicaulis L. (zig-zag goldenrod); F6123	BF, NMF	
Solidago gigantea Aiton (giant goldenrod); F6077, F6112, F6568, M7227, P43871, P44144, P44175, *T5379*	BF, NMF	
Solidago hispida Willd. (hairy goldenrod); P43910, *T5125*	PB, NDF	
Solidago juncea Aiton (early goldenrod); H3388, P43895, *T5122*	PB	
Solidago nemoralis Aiton (gray goldenrod); H3527, M6776, M7223, P43894, *T5121, T5123*	PB	
Solidago ptarmicoides (Torr. & A. Gray) B. Boivin (upland white goldenrod); H4094, *T5133, T5380*	PB	
Solidago speciosa Nutt. (showy goldenrod); M6796, M7224	PB	
Solidago uliginosa Nutt. (bog goldenrod); M6877, P44149, *T5120, T5340*	WC, NHS, BSS	
**Sonchus arvensis* L. (field sow-thistle); F6126, F6584	BF	
**Sonchus oleraceus* L. (common sow-thistle); H4117	D	WS
Symphyotrichum boreale (Torr. & A. Gray) Á. Löve & D. Löve (northern bog aster); *T5124, T5140*	WC	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Symphyotrichum ciliolatum (Lindl.) Á. Löve & D. Löve (northern heart-leaved aster); M7221, M7225, P43863, *T5136*	BF, PB, NDF	
Symphyotrichum laeve (L.) Á. Löve & D. Löve (smooth aster); M6740, P43912, *T5185, T5132*	PB	
Symphyotrichum lanceolatum (Willd.) G. L. Nesom var. *lanceolatum* (panicled aster); F6111, F6585, M6789, S25, *T5138, T5368*	W-NF, NHS	
Symphyotrichum lateriflorum (L.) Á. Löve & D. Löve (calico aster); F6075, P43870, P44150, P44182, S22	BF, NMF	
Symphyotrichum ontarionis G.L. Nesom (Ontario aster); H4020	BF	WS
Symphyotrichum oolentangiense (Riddell) G. L. Nesom (sky blue aster); M6777, P43889, *T5567*	PB	
Symphyotrichum pilosum (Willd.) G. L. Nesom (frost aster); *T5135*	PB	
Symphyotrichum puniceum (L.) Á. Löve & D. Löve (swamp aster); M6822, M6868, M7239, P44138, *T5485, T5565*	NHS, W-NF	
Symphyotrichum urophyllum (DC.) G. L. Nesom (arrow-leaved aster); H4170, H4615	PB	CR
**Tanacetum vulgare* L. (common tansy); F6583, H4106	BF, NDF	WS
**Taraxacum officinale* F. H. Wigg (common dandelion); F5636	BF, NMF	WS
Tephroseris palustris (L.) Rchb. (marsh groundsel); *Cheney 7419*	W-NF	
**Tragopogon dubius* Scop. (lesser goat's beard); P44018, P44050, P44016, S277, *T5252*	PB	WS
BALSAMINACEAE (Touch-Me-Not Family)		
Impatiens capensis Meerb. (orange jewel-weed); F6506, F6574, M7315, *Ts.n.*	NHS, WC	
BERBERIDACEAE (Barberry Family)		
Caulophyllum thalictroides (L.) Michx. (blue cohosh); S72, *T5568*	BF	
BETULACEAE (Birch Family)		
Alnus incana (L.) Moench (speckled alder); F5642, F6071, F6511, F6533, M6836, M7253, P44098, P44211, *T5052*	BF, NHS, W-NF	
Alnus viridis (Chaix) DC. (green alder); *Ts.n.*	NDMF	
Betula alleghaniensis Britton (yellow birch); H3973, S122, *T5492, T5540*	NMF	
Betula papyrifera Marshall (paper birch); M6677	BF, NDF	
Betula pumila L. (bog birch); F6378, S87	BSS	
Carpinus caroliniana Walter (American hornbeam); H3439	NFM, NDMF	
Corylus americana Walter (American hazelnut); P43918, M7144, M7213, P44009, P44038, F6354, P44186, *T5382, T5545*	PB, NDMF	
Corylus cornuta Marshall (beaked hazelnut); F6410, F6342, M7172, P44187, *Ts.n.*	BF, NMF	
Ostrya virginiana (Mill.) K. Koch (ironwood); M7011, M7140, P44189, *T5537*	BF, NMF	

BORAGINACEAE (Borage Family)		
Cynoglossum boreale Fernald (northern wild comfrey); F6049, H4050	BF, NDMF	
Lithospermum canescens (Michx.) Lehm. (hoary puccoon); M6687, M6798, P44039, S96, *T5227, T5371, T5383*	PB, NDF	
Lithospermum caroliniense (J. F. Gmel.) MacMill. (hairy puccoon); *T5377*	PB	
**Lithospermum officinale* L. (gromwell); *Epstein s.n.*	PB	
**Myosotis arvensis* (L.) Hill (field forget-me-not); P43762	BF	CR
**Myosotis scorpioides* L. (forget-me-not); F6142, M6965, M7264, *Ts.n.*	BF, AP, WC	
**Myosotis sylvatica* Hoffm. (garden forget-me-not); H3817	BF, NMF	WS
BRASSICACEAE (Mustard Family)		
Arabidopsis lyrata (L.) O'Kane & Al-Shehbaz (sand cress); H3493, *T5560*	PB	WS
**Barbarea vulgaris* W. T. Aiton (yellow rocket); S58, S101	BF, NHS	
**Berteroa incana* (L.) DC. (hoary alyssum); S286, *T5563*	NDMF	
Cardamine concatenata (Michx.) O.Schwarz (toothwort); H3895, S73	BF	WS
Cardamine pensylvanica Willd (Pensylvania bitter-cress); H3869, M6964	BF, NHS	WS
Cardamine pratensis L. var. *palustris* Wimm. & Grab (cuckoo flower); H3896	BF	CR
**Erysimum cheiranthoides* L. (wormseed mustard); *Gerst s.n.*	D	
**Lepidium densiflorum* Schrad. (small pepper grass); H3380, S281, *T5201*	D	
**Nasturtium officinale* W. T. Aiton (water cress); H3658, M7271, *T5272*	AP, NHS, WC	
Rorippa palustris (L.) Besser (yellow cress); *T5179*	D	
**Sisymbrium altissimum* L. (tumble mustard); *Gerst s.n.*	D	
**Thlaspi arvense* L. (penny-cress); *Gerst s.n.*	D	
Turritis glabra L. (tower mustard); H3376, H3672, M6820, S210	PB	
CABOMBACEAE (Water-shield Family)		
Brasenia schreberi J.F. Gmel. (water-shield); H3642	AP	WS
CAMPANULACEAE (Bell Flower Family)		
Campanula aparinoides Pursh (marsh bellflower); F6554, *T5085*	NHS, W-NF	
**Campanula rapunculoides* L. (creeping bellflower); H3704, S275	NDF, NDMF	WS
Campanula rotundifolia L. (harebell); M6738, M7155, P44055, *T5384*	PB, NDF, NDMF	
Lobelia inflata L. (Indian tobacco); H3856, M7161	PB, NDF, NDMF	
Lobelia spicata Lam. (spiked lobelia); S290	D	WS
CANNABACEAE (Hemp Family)		
Humulus lupulus L. (common hops); H3861, F6578, *T5355*	BF	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
CAPRIFOLIACEAE (Honeysuckle Family)		
Lonicera canadensis Marshall (American fly honeysuckle); F5616, P43759, P43773, M6663, M6963, F6309, M7053, *T5390*	BF, WC	
Lonicera dioica L. (mountain honeysuckle); H3825	NDF, NDMF	
Lonicera hirsuta Eaton (hairy honeysuckle); H3368, F6144, F6359, M6888	PB, NDF, NDMF	WS
**Lonicera morrowii* A. Gray (Asian fly honeysuckle); H3968	BF, NHS	WS
Lonicera oblongifolia (Goldie) Hook. (swamp fly honeysuckle); S214, *T5239*	BF, WC, NDMF	
**Lonicera tatarica* L. (Tartarian honeysuckle); F6059	BF, NHS	WS
Lonicera villosa (Michx.) Schultes (mountain fly honeysuckle); F6025, M6668, S31, S60, T5237	BF, NHS	
**Lonicera* ×*bella* Zabel (hybrid honeysuckle); S132	BF, NMF	WS
Symphoricarpos albus (L.) S. F. Blake (snowberry); H3865, M6819, M7217, *T5181*	PB, NDF, NDMF	
Symphoricarpos occidentalis Hook. (wolfberry); *T5480*	NDMF	
Triosteum aurantiacum E. P. Bicknell (early horse-gentian); H3521, P43873	BF	CR
CARYOPHYLLACEAE (Pink Family)		
**Arenaria serpyllifolia* L. (thyme-leaved sandwort); S97	BF	CR
**Cerastium fontanum* Baumg. (mouse-ear chickweed); H3897, S112, *T5198, T5324*	NDF, NDMF	
**Dianthus barbatus* L. (sweet-William); H3666, H3667	NMF	CR
**Gypsophila muralis* L. (cushion baby's breath); M6855	D	CR
Moehringia lateriflora (L.) Fenzl (wood sandwort); P43772	BF	CR
**Scleranthus annuus* L. (knawel); H3908, M6756, S76, *T5094*	PB, NDF	
Silene antirrhina L. (sleepy catchfly); M6758	PB	WS
**Silene dichotoma* Ehrh. (forked catchfly); *Fassett 9226*	PB	
**Silene latifolia* Poir. (white campion); S160, *T5258*	PB, NDF, NMDF	
**Silene vulgaris* (Moench) Garcke (bladder campion); H3728, S201, *T5392*	PB, NDMF	
**Spergularia rubra* (L.) J.Presl & C.Presl (red sand spurry); P44057, S152	NDF	CR
Stellaria borealis Bigelow (northern stitchwort); *Davis s.n., Koch 5800*	WC	
**Stellaria graminea* L. (starwort); *Gerst s.n.*	D	
Stellaria longifolia Willd. (long-leaved chickweed); M6709, M7034, M6980, M7062, S176, *T5260*	WC, NHS	
CELASTRACEAE (Bittersweet Family)		
Celastrus scandens L. (American bittersweet); F6596, *T5354*	BF	

CERATOPHYLLACEAE (Hornwort Family)		
Ceratophyllum demersum L. (coon's tail); F6559, H3761, H3577, *T5192, T5272*	AP	
CISTACEAE (Rock-Rose Family)		
Crocanthemum bicknellii (Fernald) Janch. (Bicknell's rock-rose); H3934, M6732	PB	WS
Crocanthemum canadense (L.) Britton (common frostweed); P43902, P43902, *T5393*	PB	
Lechea intermedia Britton (intermediate pinweed); M6803, M6816, M7156, P43921	PB, NDF	WS
CONVOLVULACEAE (Morning Glory Family)		
Calystegia spithamaea (L.) Pursh (low bindweed); M6751, P44011, S144, *T5333, T5514*	PB, NDF, NDNF	
CORNACEAE (Dogwood Family)		
Cornus alternifolia L. f. (pagoda dogwood); P44188, *T5522*	BF, WC, NMF	
Cornus canadensis L. (bunchberry); F6137, F6314, F6434, M6869, M7005, M7027, M7174, P43761, P44194, *T5138*	BF, WC, NMF	
Cornus foemina Mill. subsp. *racemosa* (Lam.) J. S. Wilson (gray dogwood); H4045, S208, *T5253*	BF, NDF	
Cornus rugosa Lam. (round-leaved dogwood); F6078, F6510, F6593, H3975, H3709, *T5404*	BF, NDMF	
Cornus sericea L. (red-osier dogwood); F6048, F6116, F6484, F6566, M6989, M7287, *T5081, T5563*	BF, NHS, BSS	
CUCURBITACEAE (Gourd Family)		
Echinocystis lobata (Michx.) Torr. & A. Gray (wild cucumber); H4053	BF, NHS	
DIERVILLACEAE (Bush-honeysuckle Family)		
Diervilla lonicera Mill. (bush honeysuckle); F6134, F6143, F6345, M7121, P43908, *T5403*	PB, NDF	
DROSERACEAE (Sundew Family)		
Drosera intermedia Hayne (spoon-leaved sundew); M7193, P44069, P44126	W-NF	CR
Drosera rotundifolia L. (round-leaved sundew); F6403, M6901, F6460, *T5314, T5551*	WC, BSS, W-NF	
ELAEAGNACEAE (Oleaster Family)		
Shepherdia canadensis (L.) Nutt. (soapberry); F6044, H3373, H3554, *Ts.n.*	BF	
ERICACEAE (Heath Family)		
Andromeda glaucophylla Link (bog rosemary); A2609, F6437, F6442, P44094, P44122, *T5550*	BSS, W-NF	
Arctostaphylos uva-ursi (L.) Spreng. (bearberry); P44026, *T5097*	PB, NDF	
Chamaedaphne calyculata (L.) Moench (leatherleaf); F6374, F6433, F6449, M7022, M7182, M7251, P44080, P44114	WC	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Chimaphila umbellata (L.) W. P. C. Barton (pipsissewa); M6764, M7150, M7189, P44045, P44190	BF, NDF, NDMF	
Epigaea repens L. (trailing arbutus); H3510, P44041, S59, *T5106, T5306*	PB, NDF	
Gaultheria hispidula (L.) Bigelow (creeping snowberry); F5633, F6013, F6422, M7025	WC, BSS	
Gaultheria procumbens L. (wintergreen); F6102, M6679, M7024, M7151, M7169, P44028, P44192	BF, WC, PB	
Hypopitys monotropa Crantz. (pinesap); A2612, M7152	WC, NMF	
Kalmia polifolia Wangenh. (bog-laurel); M7021, M7185, M7255, F6377, P44090, P44121, *T5313, T5549*	WC, BSS, W-NF	
Moneses uniflora (L.) A. Gray (one-flowered pyrola); F5609, F6006, F6018, F6321, H3829, P43864, *T5104, T5241*	BF, WC, NDF	
Monotropa uniflora L. (Indian-pipe); F6007, F6416, M7130, P44172, P44193	WC, NDF, BSS	
Orthilia secunda (L.) House (one-sided pyrola); F5617, F6004, M6667, M6676, M6763, M6829.1, M6870, P44168, H3830, *T5389*	WC, NDMF	
Pyrola americana Sweet (American wintergreen); H3525, M6762, M7145, M7148, P43874, P44171	BF, NDMF	CR
Pyrola asarifolia Michx. (pink shinleaf); F6131, H3801, H3845, *T5511, T5561*	BF, NMF	
Pyrola chlorantha Sw. (green shinleaf); S32, S78, *T5245*	BF, WC	
Pyrola elliptica Nutt. (large-leaved shinleaf); F6032, F6090, F6127, M6834, M7128, P44042, P44164	BF, NDMF	
Pyrola minor L. (snowline wintergreen); M6829.2	WC	END, WS
Rhododendron groenlandicum (Oeder) Kron & Judd (labrador tea); F6390, M6894, M7017, M7165, F6367, M7256, F6429, P44071	BSS, NHS	
Vaccinium angustifolium Aiton (early low blueberry); F6402, F6421, M6660, M6680, M7020, P43767, P44002, P44127, *T5183, T5184, T5336*	BF, WC, NDMF	
Vaccinium macrocarpon Aiton (large cranberry); F6438, F6472, P44118, P44130	WC	WS
Vaccinium myrtilloides Michx. (velvet-leaf blueberry); F6431, M6661, M7019, P43788, P44008	BSS, WC	WS
Vaccinium oxycoccos L. (small cranberry); F6396, F6438, F6472, M7026, M7178, M7254, P44065, *T5552*	WC, BSS	
Vaccinium vitis-idaea L. (lingonberry); Photo	WC	END
EUPHORBIACEAE (Spurge Family)		
Euphorbia glyptosperma Engelm. (rib-seed sand mat); S260	PB	
Euphorbia maculata L. (spotted sand-mat); S259	PB	
FABACEAE (Pea and Bean Family)		
Amphicarpaea bracteata (L.) Fernald (American hog peanut); F6085, F6586, *T5343*	NDMF, NMF	
Astragalus canadensis L. (Canadian milkvetch); F6051	BF	WS
Hylodesmum glutinosum (Willd.) H. Ohasi & R.R. Mill (pointed tick-trefoil); H3883	BF	CR
Lathyrus japonicus Willd. (beach pea); F6597	LSS	

Lathyrus ochroleucus Hook. (cream pea); F5666, F6364, P44029, *T5325*	BF, NDF, NMF	
Lathyrus venosus Willd. (veiny pea); S255, *T5509, T5518*	BF	
Lespedeza capitata Michx. (round headed bush clover); *T5348*	PB	
**Lotus corniculatus* L. (bird's foot trefoil); S150	BF, NDMF	WS
**Lupinus polyphyllus* Lindl. (garden lupine); S130	NMF	
**Medicago lupulina* L. (black medic); H4065	BF	WS
**Melilotus albus* Medik. (white sweet-clover); S203	BF, NHS	WS
**Melilotus officinalis* (L.) Pall (yellow sweet-clover); S151	D	WS
**Robinia pseudoacacia* L. (black locust); *T5169*	NDMF	
**Securigera varia* (L.) Lassen (crown-vetch); H4107	BF	WS
**Trifolium arvense* L. (rabbit-foot clover); S158, S268, S284	BF	WS
**Trifolium aureum* Pollich (hop clover); M7157, S197, *T5386*	BF, NDF	
**Trifolium campestre* Schreb. (low hop clover); *Gerst s.n.*	NDF	
**Trifolium hybridum* L. (alsike clover); S269, *T5520*	NDF	
**Trifolium pratense* L. (red clover); *Christensen s.n.*	BF, NDF	
**Trifolium repens* L. (white clover); S192	BF, NDF	
Vicia americana Willd. (American vetch); M7002, M7157, S148, *T5576*	BF, NMF	
**Vicia cracca* L. (cow vetch); M7153	NDF	CR
**Vicia sativa* L. (common vetch); H4064	D	
**Vicia villosa* Roth (hairy vetch); *T5524*	D	
FAGACEAE (Beech Family)		
Quercus ellipsoidalis E. J. Hill (northern pin oak); P43855, *T5102, T5189*	PB, NDMF	
Quercus macrocarpa Michx. (bur oak); *T5218, T5264, T5349, T5542, T5578*	PB, NDMF	
Quercus rubra L. (red oak); P44214, *T5515*	PB, NDMF	
GENTIANACEAE (Gentian Family)		
Gentiana alba Nutt. (pale gentian); H4055	W-NF	CR
Gentiana andrewsii Griseb. (bottle gentian); H1924	W-NF	
Gentiana rubricaulis Schwein. (red-stemmed gentian); *T5509*	W-NF	
Halenia deflexa (Sm.) Griseb. (spurred gentian); M6711, M6853, M6887, P44176	BF, NDMF	
GERANIACEAE (Geranium Family)		
Geranium bicknellii Britton (Bicknell's geranium); H3796, M7133, *T5161*	PB, BG	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
GROSSULARIACEAE (Gooseberry Family)		
Ribes americanum Mill. (wild black current); F5635, S54, *T5334, T5521*	BF, NMF	
Ribes cynosbati L. (prickly wild gooseberry); F5648, H3710, M7129	BF, NMF	
Ribes glandulosum Grauer (skunk current); A2443, A2445, M6646, M6654.2, M6973, *T5537, T5555*	WC, NHS	
Ribes hirtellum Michx. (swamp gooseberry); F5665, F6483, M6655, M7060, S49, *Ts.n.*	WC, NMF, BSS	
Ribes hudsonianum Richardson (northern black current); F5606, F6024, F6039, M6645	WC, NHS	
Ribes lacustre (Pers.) Poir. (bristly black current); M6729, P43782	BF, WC	CR
Ribes oxyacanthoides L. (northern gooseberry); M6988, S51, S91	NHS	THR, WS
Ribes triste Pall. (swamp red current); F5619, F6054, F6502, M6647, M6654.1, M7061, *T5537*	BF, WC, NHS	
HALORAGACEAE (Water-milfoil Family)		
Myriophyllum heterophyllum Michx. (various leaved water-milfoil); H3578	AP	WS
Myriophyllum sibiricum Komarov (spiked water-milfoil); F6562, F6530, H3580, M7312, *T5193, T5273*	AP	
Myriophyllum tenellum Bigelow (slender water-milfoil); S234, *T5541*	AP	
Myriophyllum verticillatum L. (water-milfoil); F6562	AP	
HYPERICACEAE (St. John's Wort Family)		
Hypericum ascyron L. (giant St. John's-wort); F6514, S271, *T5288*	W-NF	
Hypericum canadense L. (Canadian St. John's-wort); H3699	W-NF	WS
**Hypericum perforatum* L. (common St. John's-wort); H4105, M7160	PB, NDF	WS
Triadenum fraseri (Spach) Gleason (marsh St. John's-wort); F6461, F6541, M7244, M7308, P44084, P44200, *T52890*	W-NF	
LAMIACEAE (Mint Family)		
Agastache foeniculum (Pursh) Kuntze (blue giant hyssop); M6757, *T5508*	PB	
**Ajuga genevensis* L. (bugle); *Clark 1264*	BF	
Clinopodium vulgare L. (wild basil); H3374, H3749	NMF	CR
Dracocephalum parviflorum Nutt. (American dragonhead); M6818	PB	WS
**Galeopsis tetrahit* L. (hemp-nettle); M7230, *Ts.n.*	PB, NDMF	
**Glechoma hederacea* L. (creeping-Charlie); S106	BF, NDMF	
Lycopus americanus W. P. C. Barton (common water horehound); H3846, S285, *T5482*	NHS, W-NF	
Lycopus uniflorus Michx. (northern bugleweed); F6542, M6847, M6893, M7259, P44075, P44140, *T5273, T5481*	NHS, W-NF	
Mentha canadensis L. (wild mint); S272, *T5480*	BF, NHS, WC	

Monarda fistulosa L. (wild bergamot); H3721, M7222, *T5077*	PB, NDF	
Prunella vulgaris L. (self-heal); S180, *T5263*	NDMF, NDF, PB	
Scutellaria galericulata L. (marsh skullcap); F6550, H3772, P44091, *Ts.n.*	WC, NHS, W-NF	
Scutellaria lateriflora L. (mad-dog skullcap); F6507, F6550, M6861, M7276, P44101, P44162	NHS, NMF	
Stachys arenicola Britton (marsh hedge nettle); H3947	PB, NHS	
Stachys tenuifolia Willd. (smooth hedge nettle); H4103, M6783	WC, PB	
LENTIBULARIACEAE (Bladderwort Family)		
Utricularia intermedia Hayne. (northern bladderwort); F6538, M7233, P44135	AP	WS
Utricularia minor L. (lesser bladderwort); F6563, H3646, H3695, H3972	AP	WS
Utricularia vulgaris L. subsp. *macrorhiza* (J. Le Conte) R. T. Clausen (common bladderwort); F6531, H3620, P44216, S240	AP	
LINDERNIACEAE (False Pimpernel Family)		
Lindernia dubia (L.) Pennell (false pimpernel); *T5484*	W-NF	
LINNAEACEAE (Twinflower Family)		
Linnaea borealis L. (twinflower); F6304, M6760, M7008, P44032, *T5248*	NDMF, WC, BG	
LYTHRACEAE (Loosestrife Family)		
Decodon verticillatus (L.) Elliott (swamp loosestrife); S243	W-NF	CR
**Lythrum salicaria* L. (purple loosestrife); F6477, H4115, S239	W-NF	
MALVACEAE (Mallow Family)		
Tilia americana L. (basswood); *Koch 12273*	NMF, BF	
MENYANTHACEAE (Buckbean Family)		
Menyanthes trifoliata L. (buckbean); P44089, S168, *T5560*	W-NF, BSS	
MOLLUGINACEAE (Carpetweed Family)		
Mollugo verticillata L. (carpetweed); *T5174, T5082*	PB, NDF	
MYRICACEAE (Bayberry Family)		
Comptonia peregrina (L.) J. M. Coult. (sweet fern); F6405, M6686, M6734, P43905, P44001, *T5519*	PB, BF	
Myrica gale L. (sweet gale); F6535, M7265	WC, NHS	
MYRSINACEAE (Myrsine Family)		
Lysimachia ciliata L. (fringed loosestrife); F6151, S28	BF, NDMF	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Lysimachia quadrifolia L. (whorled loosestrife); A2483, M7149, P43851, P43900, *T5513, T5541*	PB, NDF	
Lysimachia terrestris (L.) Britton, Sterns & Poggenb. (swamp candles); A2608, F6456, M7180, P44072, P44123, P44197, *T5561*	NHS, W-NF	
Lysimachia thyrsiflora L. (tufted loosestrife); F6391, H3623, M7059, P44141, S171, *T5302*	WC, W-NF	
Trientalis borealis Raf. (star flower); P43752, P44034, *T5316*	WC, PB, NDMF	
NYMPHAEACEAE (Water Lily Family)		
Nuphar microphylla (Pers.) Fernald (small yellow pond lily); S250	AP	
Nuphar variegata Durand (yellow pond lily); F6527,S249, T5486	AP	
Nymphaea odorata Aiton. (fragrant water-lily); H3655, P44199, S236	AP	WS
OLEACEAE (Olive Family)		
Fraxinus americana L. (white ash); S121	NMF	
Fraxinus nigra Marshall (black ash); M6967, M7054, M7236, *T5546, T5557*	NHS, WC	
Fraxinus pennsylvanica Marshall (green ash); F6582, S44, *T5364*	BF, NMF	
ONAGRACEAE (Evening-Primrose Family)		
Chamerion angustifolium (L.) Holub (fireweed); A2606, M6791, M7192	PB, NDF	WS
Circaea alpina L. (small enchanter's nightshade); M6843, M6889, M7052, P44106, S174, *T5090, T5246*	WC, NHS	
Circaea canadensis (L.) Hill (broad-leaf enchanter's-nightshade); H3708, H3877, M7139	NHS, NMF	WS
Epilobium ciliatum Raf. (willow herb); F6135, F6569, M7279, M7314, *T5274*	WC, NHS	
Epilobium coloratum Biehler (cinnamon willow herb); M6878, P44159	WC, NHS	
Epilobium leptophyllum Raf. (American marsh willow-herb); F6476, M6833, M6857, M7299	WC, W-NF	
Epilobium palustre L. (marsh willow-herb); M6896, S190	WC	
Ludwigia palustris (L.) Elliott (marsh purslane); H3588	W-NF	WS
Oenothera biennis L. (common evening primrose); H3726, H4100, P43899	PB, NDMF	
Oenothera clelandii W. Dietr., Raven & W.L. Wagner (evening primrose); M6744	PB	CR
Oenothera perennis L. (small evening primrose); *Goessl 7644*		
Oenothera villosa Thunb. (evening primrose); M6780	PB	WS
OROBANCHACEAE (Broom-rape Family)		
Agalinis paupercula (A. Gray) Britton (smooth false foxglove); H1918	W-NF	
Conopholis americana (L.) Wallr. (American cancer-root); A2604, M7100, M7110	NMF	CR
**Euphrasia stricta* J. F. Lehm. (drug eye-bright); M6856, P44215	PB	WS

Melampyrum lineare Desr. (cow-wheat); A2488, F6412, M6733, M6761, M7142, M7190, P44023, *T5562*	PB, NDF	
Pedicularis canadensis L. (wood-betony); F6355, H3398, M6695, P44046, *T5317*	PB, NDF	
OXALIDACEAE (Wood-sorrel Family)		
Oxalis acetosella L. subsp. *montana* (Raf.) D. Löve (mountain wood-sorrel); M6890, P44111, S179	WC, NHS	WS
Oxalis dillenii Jacq. (southern yellow wood-sorrel); M6805	BF, WC	WS
Oxalis stricta L. (wood-sorrel); H4073, S198	PB, NDF	WS
PAPAVERACEAE (Poppy Family)		
Capnoides sempervirens (L.) Borkh. (pink corydalis); F5650, M7132, *T5338, T5423*	BG	
Sanguinaria canadensis L. (bloodroot); H3564	BF	
PENTHORACEAE (Stonecrop Family)		
Penthorum sedoides L. (ditch stonecrop); *T5283*	W-NF	
PHRYMACEAE (Lopseed Family)		
Mimulus glabratus Kunth (James' monkey-flower); H4054, M7305, *T5191*	W-NF	
Mimulus ringens L. (monkey-flower); F6560, *T5284*	WC	
PLANTAGINACEAE (Plantain Family)		
Callitriche hermaphroditica L. (autumnal water starwort); H4016, M7291, *T5278, T5357, T5510*	AP	SC
Callitriche palustris L. (water starwort); F6015, M6903, M7270, *T5280, T5281, T5378*	AP	
Chelone glabra L. (turtle head); F6113, F6582, F6594, M6831, M6872, M7241, M7280, P44147	BF, W-NF	
Hippuris vulgaris L. (common mare's will); M7297	AP	WS
**Linaria vulgaris* Mill (butter and eggs); *T5565*	D	
Nuttallanthus canadensis (L.) D. A. Sutton (blue toad-flax); *Judziewicz 11400*	PB, NDF	
**Plantago major* L. (broad-leaved plantain); P43858	PB, NDF	WS
**Plantago patagonica* Jacq. (woolly plantain); M6804	PB	WS
Plantago rugelii Decne. (American plantain); H3903, P44165	BF, NDF	CR
Veronica beccabunga L. var. *americana* Raf. (American brooklime); F6003, M6900, M7268	WC, NHS	
**Veronica longifolia* L. (garden veronica); F6034	BF	CR
**Veronica officinalis* L. (common speedwell); F6150, H3479, M7001, M7095	BF, NDMF	
Veronica peregrina L. (purslane speedwell); *Judziewicz 10701, Koch 12277*	D	
Veronica scutellata L. (marsh speedwell); P44096	W-NF	WS
Veronica serpyllifolia L. (thyme-leaved speedwell); *Gilbert,s.n.*	BF, NDMF	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
POLYGALACEAE (Milkwort Family)		
Polygala paucifolia Willd. (fringed polygala); F5620, F6315, P43850	WC, NDMF	
Polygala polygama Walter (racemed milkwort); M6737, M6797, M6813, P44052, S216, *T5394*	PB, NDF	
Polygala sanguinea L. (field milkwort); *Garske 770*	D	
POLYGONACEAE (Buckwheat Family)		
Fallopia cilinodis (Michx.) Holub (fringed black bindweed); F6334, F6499, M7124, P43861	WC, NHS	WS
**Fallopia convolvulus* (L.) Á. Löve (black bindweed); M6814, P43911, S204	BF, PB	
Fallopia scandens (L.) Holub (false buckwheat); F6334, H4101	BF, NDMF	
Persicaria amphibia (L.) Delabare (water smartweed); P44210, S247, *T5550*	BSS	
**Persicaria hydropiper* (L.) Delabare (marsh-pepper knotweed); M7286	W-NF	WS
Persicaria lapathifolia (L.) Delabare (nodding smartweed); F6537, *T5178*	W-NF	
**Persicaria maculosa* Gray (curly-top knotweed); H3969, H4104	W-NF	WS
Persicaria pensylvanica (L.) M. Gómez (Pensylvania knotweed); H3529	WC	WS
Persicaria punctata (Elliott) Small (dotted smartweed); H3765	W-NF	WS
Persicaria sagittata (L.) H. Gross (arrow-leaved tear-thumb); M6865, P44157, *T5286*	WC, W-NF	
Polygonella articulata (L.) Meisn. (coastal joint weed); M6801, P43887	PB	WS
Polygonum achoreum S. F. Blake (leathery knotweed); *T5171*	PB	
**Polygonum aviculare* L. (prostrate knotweed); *T5101, T5198*	NDF	
**Rumex acetosella* L. (sheep sorrel); S89, S282, *T5323*	PB, NDF	
**Rumex crispus* L. (curly dock); H4049, S154, *T5233*	BF, NHS	
**Rumex obtusifolius* L. (bitter dock); H3745	BF	WS
Rumex orbiculatus A. Gray (great water dock); F6522, M7243, M7269, P44161, *T5083*	W-NF	
PORTULACACEAE (Purslane Family)		
**Portulaca oleracea* L. (purslane); *T5381*	PB	
RANUNCULACEAE (Buttercup Family)		
Actaea pachypoda Elliott (doll's-eyes); H3608, H3715	NMF	WS
Actaea rubra (Aiton) Willd. (red baneberry); F6132, F6313, F6480, M6876, *T5519, T5530, T5546*	BF, WC, NDMF	
Anemone americana (DC.) H. Hara (round-leaved hepatica); F5612, S41, *T5307*	BF, NMF	
Anemone canadensis L. (Canada anemone); S94, S138, *T5326*	BF, NDMF	
Anemone cylindrica A. Gray (thimbleweed); F6047	PB	WS
Anemone quinquefolia L. (wood anemone); F5622, F6351, M6653, M6682, M7007, P43753, *T5309,*	BF, NDF, NMF	

T5505, T5222		
Anemone virginiana L. (thimbleweed); F6128, S23	BF	
Aquilegia canadensis L. (wild columbine); F6333, F5653, *T5327*	BF, NDF, NMF	
Caltha palustris L. (marsh marigold); F5638, F6322, M6652, M6962, M7042	WC, W-NF	
Clematis occidentalis (Hornem.) DC. (purple clematis); *Sasse, s.n.*	WC	
Clematis virginiana L. (virgin's bower); F6572, H3939, H3980, H4056, *T5326*	BF, NHS	
Coptidium lapponicum (L.) Rydb. (Lapland buttercup); F6366	WC	END
Coptis trifolia (L.) Salisb. (goldthread); F5607, M6644, P44112, *T5092, T5093, T5232*	BF, WC, NMF	
Ranunculus abortivus L. (kidney-leaved buttercup); M6986, *T5422*	BF, NDMF	
**Ranunculus acris* L. (tall buttercup); F6082, M6961, S115	BF, NMF	
Ranunculus hispidus Michx. (bristly buttercup); H3594, H3716, H3820, M6971	BF, NHS, NMF	WS
Ranunculus longirostris Godr. (aquatic buttercup); H3759, H3862, M7277, S221, *T5166, T5279, T5295*	AP	
Ranunculus pensylvanicus L. f. (bristly buttercup); H3984, M7311	BF, NHS, NMF	
Ranunculus recurvatus Poir. (hooked buttercup); F6500, H3596, M6719, M7057	BF, NHS, NMF	WS
Ranunculus sceleratus L. (celery-leaf buttercup); H3396	WC	WC
Thalictrum dasycarpum Fisch. & Avé-Lall. (purple meadow-rue); F6120, F6512, M6715, M6867, *T5490, T5507*	BF, WC, NHS	
Thalictrum dioicum L. (early meadow-rue); F5629, F6350, M6653, M6682, P43753	BF, WC, NHS	WS
RHAMNACEAE (Buckthorn Family)		
Ceanothus americanus L. (New Jersey tea); *Clark 98*	NDF	
Ceanothus herbaceus Raf. (Jersey tea); P43911, P44054, *T5331*	PB	
Rhamnus alnifolia L'Her. (alder-leaved buckthorn); A2444, H3587, M6657, S188, *T5240, T5529*	BF, NHS	
**Rhamnus cathartica* L. (common buckthorn); M7232, S167, S288	BF, NDMF, NHS, NMF	
ROSACEAE (Rose Family)		
Agrimonia gryposepala Wallr. (tall agrimony); F6045, F6081, F6497, P43872, S24	BF, NHS, NMF	
Agrimonia striata Michx. (roadside agrimony); *T5269*	WC	
Amelanchier arborea (F. Michx.) Fernald (common serviceberry); F6344, F6435, H3365, S62	BF, WC, NDMF	WS
Amelanchier bartramiana (Tausch) M. Roem. (mountain Juneberry); H3599	BSS	
Amelanchier interior Nielsen (inland serviceberry); F6481, H3904, M6669	WC	
Amelanchier laevis Wiegand (smooth serviceberry); H3597	BF, WC, NDMF	
Amelanchier sanguinea (Pursh) DC. (round-leaved serviceberry); F5655, F6043, F6344, M6671, M7120, P43999, P44044, *T5514*	BF, WC, NDMF	
Amelanchier spicata (Lam.) K. Koch (shadbush serviceberry); M6697	PB	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Aronia melanocarpa (Michx.) Elliott (chokeberry); P44204	NDF, BSS	
Aronia x prunifolia (Marshall) Rehder (chokeberry); *T5554*	W-NF	
Comarum palustre L. (marsh cinquefoil); A2607, F6399, F6453, F6547, M7166, P44077, P44124	WC, NHS, BSS	
Crataegus chrysocarpa Ashe (hawthorn); A2545, P43748	BF	
Crataegus punctata Jacq. (dotted hawthorn); F6601	BF	WS
Crataegus submollis Sarg. (northern red haw); A2546, H4021	BF	CR
Crataegus succulenta subsp. macracantha (hawthorn); *T5488*	BF	
Drymocallis arguta (Pursh) Rydb. (prairie cinquefoil); M6752, P43920	PB	WS
**Filipendula rubra* (Hill) B. L. Rob. (queen-of-the-prairie); *Clark 1344*	D	
Fragaria vesca L. (woodland strawberry); F6311, M7131, S156, *T5277*	BF, WC, NMF	
Fragaria virginiana Mill. (wild strawberry); F5643, M6685, M7013, P43749, *T5221, T5401*	BF, WC, NMF	
Geum aleppicum Jacq. (yellow avens); F6055, F6083, F6492, M7108, *T5275, T5512*	BF, NDF, NDMF	
Geum canadense Jacq. (white avens); F6487	BF, NHS	WS
Geum fragarioides (Michx.) Smedmark (barren strawberry); F6305, P43790, P44015, P44025, S43, *T5531*	PB, NDF	
Geum laciniatum Murray (rough avens); F6492, M6993	NHS	WS
Geum macrophyllum Willd. (large-leaved avens); (H3964, F6010)	WC, NDMF	SC, WS
Geum rivale L. (purple avens); M6726, M6859, M6898, M7044	BF, WC, NHS	
**Potentilla argentea* L. (silvery cinquefoil); H3893, *T5516*	PB, NDF	
Potentilla norvegica L. (rough cinquefoil); S155, S266, *T5188*	PB, NDF	
**Potentilla recta* L. (rough-fruited cinquefoil); S219	PB, NDF	WS
Potentilla simplex Michx. (common cinquefoil); F6356, P44014, P44051	PB, NDF	WS
Prunus americana Marshall (American plum); S52	BF, WC	WS
Prunus nigra Aiton (Canada plum); H3482, H3806, H3833, S26, *T5356, T5376*	BF, NDMF	
Prunus pensylvanica L. f. (pin cherry); H3603, M6664, M7122, M7191, *T5087, T5370*	BF, WC, NMF	
Prunus pumila L. (sand cherry); M6678, P44000, *T52226, T5405*	PB, NDF	
Prunus serotina Ehrh. (black cherry); S117, *T5300*	BF, NHS, NMF	
Prunus virginiana L. (chokecherry); F5637, F6340, F6482, F6599, M6659, M6698, P43785	BF, PB, NHS	
Rosa acicularis Lindl. (bristly rose); F5656, F6019	BF, WC, PB	WS
Rosa blanda Aiton (smooth rose); A2484, A2487, F6122, F6580, M6996, P44049, *T5513*	BF, PB, NDMF	
Rosa carolina L. (pasture rose); H3664, M6747, M6795	BF, PB, NDMF	WS
Rubus allegheniensis Porter (common blackberry); F6352, F6358, M7143, P44030, *T5517*	BF, PB, NDF	
Rubus canadensis L. (Canadian highbush blackberry); H3880, S93	NDF, NDMF	
Rubus flagellaris Willd. (short-stalk dewberry); H3384, H3385, M6767, P43903, P44003, P44036	PB, NDF	WS

Rubus hispidus L. (swamp dewberry); H3686	WC	WS
Rubus parviflorus Nutt. (thimbleberry); M7125	BF, WC, NDMF	WS
Rubus pubescens Raf. (dwarf raspberry); F5640, M6656, M6723, M6968, M7045, S61, *T5320*	BF, WC, NDMF	
Rubus setosus Bigelow (bristly blackberry); F6379, F6387, H4018, S195	PB, BSS	
Rubus strigosus Michx. (red raspberry); M6990	BF, PB, NMF	
Sibbaldiopsis tridentata (Aiton) Rydb. (three-toothed cinquefoil); A2489, M6736, M6806, P44053, *Ts.n.*	PB	
**Sorbaria sorbifolia* (L.) A.Braun (false spiraea); S258	BF	
Sorbus americana Marshall (American mountain ash); M6884	BF, NDMF, NHS, NMF	WS
**Sorbus aucuparia* L. (Eurasian mountain ash); S145	NDMF	WS
Spiraea alba Du Roi (white meadowsweet); F6465, F6546, M7170, M7267, P44079, P44113	WC, NHS, BSS	WS
Spiraea tomentosa L. (steeplebush); H2179, H4113	BSS	WS
RUBIACEAE (Madder Family)		
Galium aparine L. (cleavers); H3898, *T5538*	BF	
Galium asprellum Michx. (rough bedstraw); F6107, F6485, F6565, *T5271, T5448*	BF, WC, NMDF	
Galium boreale L. (northern bedstraw); S218	BF, PB	
Galium labradoricum (Wiegand) Wiegand (northern bog bedstraw); F6536, F6543	WC	WS
Galium tinctorium L. (stiff bedstraw); F6469, S141, S163, *T5084*	BF, NHS	
Galium trifidum L. (small bedstraw); F6536, F6543, M6982, M7304	BF, WC, NHS	
Galium triflorum Michx. (fragrant bedstraw); F6022, F6038, F6362, M7012, P44184, *T5247*	BF, NMF, NHS	
Houstonia longifolia Gaertn. (long-leaved bluets); P43915, *T5170*	PB	
Mitchella repens L. (partridgeberry); F6136, P43757, *T5421*	BF, WC, NDMF	
SALICACEAE (Willow Family)		
Populus balsamifera L. (balsam poplar); S50, *T5556*	BF, NDF, NHS	
Populus grandidentata Michx. (big-tooth aspen); H3372, H3375, S104, *T5523*	BF, NDMF	
Populus tremuloides Michx. (quaking aspen); H4743	BF, NDMF, NHS	
**Salix alba* L. (white willow); *T5363*	BF	
Salix bebbiana Sarg. (Bebb's willow); F6509, H3657, H3988	BF, NHS, NMF	
Salix candida Willd. (sage-leaved willow); H2703	W-NF	WS
Salix discolor Muhl. (pussy willow); F6020, M6665, S33, *T5484*	BF, WC, NHS	
Salix eriocephala Michx. (heart-leaved willow); S159, *T5484*	NDF, NDMF	
Salix exigua Nutt (sandbar willow); F6587, S146	W-NF	
Salix humilis Marshall (prairie willow); M6699, P43747, S37, *T5095, T5494, T5502, T5510, T5547*	PB, NDMF	
Salix lucida Muhl. (shining willow); F6470, *T5487*	W-NF	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Salix pedicellaris Pursh (bog willow); H3610, P44082, F6397, F6454, F6475	BSS	
Salix petiolaris Sm. (slender willow); F6473, S40	BSS	
Salix pyrifolia Andersson (balsam willow); F6370, F6474, M6670, P44095 P44206	WC, BSS	WS
**Salix × fragilis* L. (hybrid crack willow); S164	BF	
SANTALACEAE (Sandalwood Family)		
Comandra umbellata (L.) Nutt. (bastard toadflax); F6363, H3477, H4047, *T5330*	PB, NDF, NDMF	
SAPINDACEAE (Soapberry Family)		
Acer negundo L. (box elder); S126	BF, NHS	WS
Acer rubrum L. (red maple); P43750	BF, NDMF, NMF	WS
Acer saccharum Marshall (sugar maple); S92, S108	BF, NMF, NHS	WS
Acer spicatum Lam. (mountain maple); F5628, F5660, F6001, F6119, F6323, M6892, M7123, P43862	BF, NDF, NDMF	
SARRACENIACEAE (Pitcher-Plant Family)		
Sarracenia purpurea L. (pitcher plant); F6401, F6444, M7188, P44067, P44131, *T5567*	BSS	
SAXIFRAGACEAE (Saxifrage Family)		
Chrysosplenium americanum Hook. (golden saxifrage); H3936, M6846, *T5108, T5124*	BF, WC, NHS	
Heuchera richardsonii R. Br. (alum root); H3393, H3552, P43917, *T5204, T5301*	PB	
Micranthes pensylvanica (L.) Haw. (swamp saxifrage); F5654, M6972, M7047, *T5026*	BF, WC, NHS	
Mitella diphylla L. (bishop's cap); F5621, F5641	BF, WC	
Mitella nuda L. (naked miterwort); F5613, H3379, H3481, M6673, *T5249, T5417*	BF, WC, NHS	
SCROPHULARIACEAE (Figwort Family)		
Scrophularia lanceolata Pursh (early figwort); F6573, H4109, S136, S206, *T5564*	D	
**Verbascum thapsus* L. (mullein); H4062, S276, *Ts.n.*	PB	
SOLANACEAE (Nightshade Family)		
Physalis virginiana Mill. (Virginia ground cherry); H3888, M6750, S217, *T5180, T5407*	PB	
**Solanum dulcamara* L. (bittersweet night-shade); F6130, F6567	BF, WC, NHS	
THYMELACEAE (Mezereum Family)		
Dirca palustris L. (leatherwood); A2601, H3589, M7098	BF, NDF, NMF	
ULMACEAE (Elm Family)		
Ulmus americana L. (American elm); H3978, *T5533*	BF, NDF, NHS	

URTICACEAE (Nettle Family)		
Laportea canadensis (L.) Wedd. (wood nettle); H3983, S165, *T5554*	BF, WC, NHS	
Urtica dioica L. (stinging nettle); *T5574*	BF, NHS	
VALERIANACEAE (Valerian Family)		
**Valeriana officinalis* L. (garden valerian); F6109, F6575, P43877	BF, NDF, WC	
VERBENACEAE (Vervain Family)		
Verbena hastata L. (blue vervain); H3744, S267, *T5345*	NHS, W-NF	
VIOLACEAE (Violet Family)		
Viola adunca Sm. (hook-spur violet); M6681, M7141, M7229	PB, NDF, NDMF	WS
Viola blanda Willd. (sweet white violet); H3583, H3899, *Koch 7731*	BF, WC	
Viola cucullata Aiton (blue marsh violet); H3399, S100	BF, WC, NHS	WS
Viola labradorica Schrank (dog violet); F5626, H3600, H3613, M7014, P43754, P44174, *T5231*	BF, PB, NDMF	
Viola macloskeyi F. E. Lloyd (smooth white violet); F5627, H3583, H3899, M6666, S77, S99, *T5398*	BF, WC, NHS	
Viola pedata L. (bird's-foot violet); M6689, S74, *T5220*	PB, NDF	
Viola pubescens Aiton (yellow wood violet); F5630, P43776, *T5536, T5308*	BF, NMF, NDF	
Viola renifolia A. Gray (kidney-leaved violet); H3498, H3900, S63	BF, WC, NDMF	WS
Viola sororia Willd. (common blue violet); H4034, S71	BF, ND, NHS	WS
VITACEAE (Grape Family)		
Parthenocissus inserta (A. Kern.) Fritsch (grape woodbine); P43885	BF	WS
Parthenocissus quinquefolia (L.) Planch. (Virginia creeper); S182	BF, WC, NDMF	WS
MONOCOTS		
ACORACEAE (Sweet Flag Family)		
Acorus americanus (Raf.) Raf. (sweet-flag); H2834, *T5491*	AP	
**Acorus calamus* L. (sweet-flag); H4150, S166	AP	
ALISMATACEAE (Water-Plantain Family)		
Alisma triviale Pursh (northern water plantain); *T5351, T5483*	AP	
Sagittaria cuneata E. Sheld. (arum-leaved arrow-head); *T5259, T5477*	AP	
Sagittaria latifolia Willd. (arrow-head); F6516, H3774, H3850, *T5194, T5292*	AP	
Sagittaria rigida Pursh (stiff arrow-head); F6517, H3629, H3771, H3863, *T5282, T5291, T5293, T5339*	AP	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
ALLIACEAE (Onion Family)		
Allium tricoccum Aiton (wild leeks); H3711, M7107, S39, *T5539*	BF, NMF	
ARACEAE (Arum Family)		
Arisaema triphyllum (L.) Schott (jack-in-the-pulpit); F6338, M6852, *T5425*	BF, WC, NHS	
Calla palustris L. (wild calla); F6384, F5663, M6839, M7173, M7307, P44074, P44125, P44155, *T5251, T5551*	WC, NHS, BSS	
Lemna minor L. (common duckweed); F6540, M7237, M7266	AP	WS
Lemna trisulca L. (star duckweed); H3576, M7292	AP	WS
Lemna turionifera Landolt (red duckweed); H3955, *T5163*	AP	
Spirodela polyrrhiza (L.) Schleid. (greater duckweed); F6532, H3640, *T5163*	AP	
Symplocarpus foetidus (L.) W.P.C. Barton (skunk cabbage); S172, *T5552*	NHS	
CONVALLARIACEAE (Lily-of-the-valley Family)		
Clintonia borealis (Aiton) Raf. (blue-bead lily); F6346, F6414, M6824, M6854, M6895, M7117, M7175, P43765, P44179, *T5426*	BF, WC	
**Convallaria majalis* L. (European lily-of-the-valley); S131	BF, NHS	
Maianthemum canadense Desf. (wild lily-of-the-valley); F6094, F6365, F6413, M6347, M7116, P43768, P44024, *T5319, T5337*	BF, NDF, NMF	
Maianthemum racemosum (L.) Link (false Solomon's-seal); F6365, H3545, P44183	BF, NDF, NMF	WS
Maianthemum stellatum (L.) Link (starry false Solomon's-seal); *Schlapper, 35/03*	PB	
Maianthemum trifolium (L.) Sloboda (false may flower); F6393, F6420, M7023, P44088, *T5321, T5553*	BSS, WC	
Polygonatum pubescens (Willd.) Pursh (downy Solomon's-seal); F5659, F6349, M7118, P43858	BF, NDF, NDMF	WS
Streptopus lanceolatus (Aiton) Reveal (rose twisted stalk); F6339, H3475, M6850, P43778, S18, *T5416*	BF, NDF, NDMF	
Uvularia grandiflora Sm. (bellwort); F5645, F6056, F6113, S66	NDMF, NMF	
Uvularia sessilifolia L. (sessile bellwort); F6117, F6357, F6408, M6799, M7066, M7115, P43786, *T5312*	BF, NDF, NDMF	
CYPERACEAE (Sedge Family)		
Bulbostylis capillaris (L.) C. B. Clarke (dense tuft hair sedge); A2486	PB	
Carex adusta Boott (lesser brown sedge); M6759, P44027, P44037, *T5405*	NDF	
Carex alopecoidea Tuck. (foxtail sedge); H3811	NMF	CR
Carex aquatilis Wahlenb. (water sedge); H3999	BF, WC	WS
Carex arcta Boott (northern cluster sedge); *Christensen s.n.*	NMF	
Carex arctata Boott (drooping woodland sedge); F5661, F6027, F6095, F6153, F6310, M7096, M7010, *T5242*	BF, NDF, NDMF	

Carex assiniboinensis W.Boott (Assiniboine sedge); A3747, H3628, H3750	BF	WS
Carex aurea Nutt. (golden sedge); F6046	BF	
Carex backii W. Boott (Rocky Mountain sedge); A2603, F5649, H3419, M7127	BG	SC, CR
Carex bebbii (L. H. Bailey) Fernald (Bebb's sedge); H3907, M6704, *T5173*	WC	
Carex bromoides Willd. (brome-like sedge); H4007, H4010, M7039	BF, NHS, NMF	CR
Carex brunnescens (Pers.) Poir. (brownish sedge); F6041, M6705, M6957, M7046	BF, NHS, NMF	
Carex canescens L. (silvery sedge); M6987, M7031, M7038	WC, NHS, BSS	
Carex castanea Wahlenb. (chestnut sedge); F6152, M6707, M7004, M7094, M7109, P43751, P43764	BF, WC, NHS	
Carex chordorrhiza L. f. (cord-root sedge); F6425, H3783, M7257	BC, BSS	WS
Carex communis L. H. Bailey (fibrous root sedge); F5662, F6325, H3605, H3606, P43766, S55, *T5478*	BF, NDMF	
Carex comosa Boott (bristly sedge); H3909, M7235, P44154	NHS	WS
Carex crawfordii Fernald (Crawford's sedge); H3776, H4040, M6800	PB	
Carex crinita Lam. (fringed sedge); F6490, M6953, M7040, M7102, P44109, P44148, *T5521*	BF, WC, NHS	
Carex cryptolepis Mack. (northeastern sedge); *Goessl 7675, Sulman 747*	W-NF	
Carex debilis Michx. (northern weak sedge); M7168	NDMF, NMF	
Carex deflexa Hornem. (northern sedge); F6327, F6330, F6343, M6658, M7063	WC, NMF	
Carex deweyana Schwein. (Dewey's sedge); F6033, M6716, M7064, P43758, S57	BF, NDF, NMF	
Carex disperma Dewey (soft leaf sedge); F5632, F6012, M6643, M6712	WC, BSS	
Carex eburnea Boott (bristle-leaf sedge); H3966	WC	WS
Carex echinata Murray (star sedge); H3400, F6464	BF, WC, NHS	WS
Carex echinodes (Fernald) P.Rothr., Reznicek, & Hipp. (marsh straw sedge); F6062	BF	CR
Carex foenea Willd. (bronze-headed oval sedge); F6312, F6337, H3491	PB	
Carex gracillima Schwein. (graceful sedge); F6040, F6063, F6310, M6713, M6958, M7006, M7050, M7113, P43763	BF, NDMF, NMF	
Carex granularis Willd. (limestone meadow sedge); F6050	BF, W-NF	WS
Carex gynandra Schwein. (nodding sedge); F6053, F6070, M6717, M6727, M6880, M6899	BF, NHS, BSS	
Carex hirtifolia Mack. (hairy sedge); H3812	BF	CR
Carex houghtoniana Dewey (Houghton's sedge); *Davis s.n., Koch 5730*	W-NF	
Carex hystericina Willd. (bottlebrush sedge); F6023, M6722, M6897, M7300, *T5177*	WC, NHS, AP	
Carex interior L. H. Bailey (inland sedge); F6000, M6728, S118	WC, NHS	
Carex intumescens Rudge (greater bladder sedge); A2602, F6148, F6307, F6508, M6706, M6960, M6995, M7006, M7041, M7092, M7176, P44103, *T5250, T5539*	BF, NDMF, NMF	
Carex lacustris Willd. (lake sedge); F6371, F6549, S125	NHS, W-NF	
Carex lasiocarpa Ehrh. (woolly fruit sedge); F6381, F6451, F6471, P44129	BSS, W-NF	WS

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Carex leptalea Wahlenb. (bristly stalked sedge); F6009, M6873, M6956, M7048, P44102	WC, BSS	
Carex leptonervia (Fernald) Fernald (nerveless woodland sedge); F6026, F6324, H3592, H3601, M7036, P44102	BF, WC, NHS	
Carex limosa L. (muck sedge); F6439, H3617, P44087	W-NF	WS
Carex lurida Wahlenb. (shallow sedge); *A459*	W-NF	
Carex magellanica Lam. (boreal bog sedge); F6028, F6398, F6427, F6468, M6826, M6904, M7028, M7179, M7261	BSS, WC, W-NF	
Carex muehlenbergii Schkuhr ex Willd. (Muhlenberg's sedge); M6753	PB	CR
Carex normalis Mack. (greater straw sedge); F6147	BF, NHS	CR
Carex oligosperma Michx. (few seed sedge); F6380, F6452, M7033, M7186, M7260, P44073, P44117	BSS, WC	
Carex ormostachya Wiegand (necklace spike sedge); F6324, P43777	BF, NDMF	CR
Carex pauciflora Lightf. (few flowered sedge); M7194, P44063	W-NF	
Carex peckii Howe (Peck's sedge); F5614, F6306, H3604, H3797	NMF, BF, NDMF	WS
Carex pedunculata Willd. (long-stalk sedge); F5608, M6648, P43756	BF, WC, NMF	WS
Carex pellita Willd. (broad-leaved wooly sedge); *Koch 5718, Freckmann 29090*	WC	
Carex pensylvanica Lam. (Pennsylvania sedge); M6684, P43780, P44031, S75	PB, NDMF, NMF	
Carex projecta Mack. (necklace sedge); F6486, F6503, M6710, M6714, M6978, M6985, M6994, M6998, M7099, M7105, M7158, P44142	BF, NHS, NMF	
Carex pseudo-cyperus L. (false bristly sedge); M7302	AP	
Carex radiata (Wahlenb.) Small (eastern star sedge); H3998, M6981, M6983	BF, NHS	CR
Carex retrorsa Schwein. (deflexed bottlebrush sedge); F6140, H3748, *T5527*	BF, WC, W-NF	
Carex rosea Willd. (rosy sedge); H3595	BF, NHS	CR
Carex rostrata Stokes (beaked sedge); H2775, S273	BSS, WC	WS
Carex scabrata Schwein. (eastern rough sedge); F6084, H4011	BF, NMF	
Carex scoparia Willd. (broom sedge); H2302	BF, NMF, NHS	
Carex siccata Dewey (dry-spiked sedge); H3809, P44017	PB	WS
Carex sprengelii Spreng. (long-beaked sedge; Sprengel's sedge); H3805, P43791	BF	CR
Carex stipata Willd. (common fox sedge); F6495, M6955, M6725, P44107	BF, NDF, NMF	
Carex stricta Lam. (tussock sedge); M7032, *T5261*	BSS, WC, W-NF	
Carex tenera Dewey (quill sedge); F6145, P43998	BF, PB	
Carex tenuiflora Wahlenb. (sparse flower sedge); F6400	WC	
Carex tonsa (Fernald) E. P. Bicknell (shaved sedge); M6683, P44047, S56	PB, NDF	
Carex tribuloides Wahlenb. (blunt brome sedge); H4031	W-NF	CR
Carex trisperma Dewey (three seeded sedge); F6392, F6419, M7018, M7101, M7167, *T5244*	WC, BSS, NHS	

Carex tuckermanii Dewey (Tuckerman's sedge); M6954, M7103, M7238, *T5520*	NHS, NMF	
Carex umbellata Willd. (early oak sedge); F5647	BF	WS
Carex utriculata Boott (yellow lake sedge); F6372, F6424, F6452, F6525, M7183, P44085, P44115	NHS, BSS, W-NF	
Carex vaginata Tausch (sheathed sedge); H3403, F6017	WC	
Carex vesicaria L. (blister sedge); M6979, P44205	NHS	
Carex viridula Michx. (little green sedge); S80	WC	
Carex vulpinoidea Michx. (fox sedge); H3662	W-NF	
Carex ×knieskernii Dewey (hybrid sedge); H3714, M7009	NMF	CR
Cyperus houghtonii Torr. (Houghton's nut sedge); M6817, P43893	PB	WS
Cyperus lupulinus (Spreng.) Marcks (slender sand sedge); *Epstein s.n.*	PB	
Dulichium arundinaceum (L.) Britton (three-way sedge); H3632, P44195, S202, *T5366, T5566*	NHS, W-NF	
Eleocharis acicularis (L.) Roem. & Schult. (needle spike rush); S232	NHS, AP	
Eleocharis erythropoda Steud. (bald spike rush); H4024, *T5176*	AP, W-NF	
Eleocharis intermedia Schult. (intermediate spike rush); H3958, H4151, *T5285*	AP	
Eleocharis obtusa (Willd.) Schult. (blunt spike rush); *Svenson (1971-01-01)*	AP, W-NF	
Eleocharis ovata (Roth) Roem. & Schult. (oval spike rush); H3758	W-NF	
Eleocharis palustris (L.) Roem. & Schult. (spike rush); F6556, M7296, P44196	AP, W-NF	
Eriophorum angustifolium Honck. (narrow leaf cotton grass); F6406, H4002, S82, *T5230*	BSS, W-NF	
Eriophorum chamissonis C.A. Meyer (Chamisso's cotton grass); H2152, S81, S107	W-NF	
Eriophorum gracile W. D. J. Koch (slender leaf cotton grass); F6443, H3622, H3723	W-NF	
Eriophorum tenellum Nutt. (conifer cotton grass); A2610, F6446, M7258, P44068, P44092, P44119, P44201	W-NF	WS
Eriophorum vaginatum L. (tussock cotton grass); F6389, F6445, M7029, *T5229, T5572*	WC, BSS	
Eriophorum virginicum L. (tawny cotton grass); A2611, F6418, F6447, M7187, M7249, P44066, P44116	BSS, W-NF	
Eriophorum viridicarinatum (Engelm.) Fernald (green-keeled cotton grass); S187, *T5238*	W-NF	
Rhynchospora alba (L.) Vahl (white beak sedge); F6448, P44086	W-NF	WS
Rhynchospora fusca (L.) W. T. Aiton (brown beak sedge); A2614, F6463, H3697	W-NF	SC
Schoenoplectus acutus (Bigelow) Á. Löve & D. Löve (hard-stem bulrush); H3891	AP	WS
Schoenoplectus pungens (Vahl) Palla (chair-maker's rush); *Salomaki 97/26*	AP	
Schoenoplectus smithii (A. Gray) Sojak var. *setosus* (Fernald) S.G. Smith (Smith's bulrush); A2633, P44202	AP	WS
Schoenoplectus tabernaemontani (C. C. Gmel.) Palla (soft stem bulrush); F6520, H3769, M7301, S242, *T5358, T5479*	AP	
Scirpus atrocinctus Fernald (black-girdled wool-grass); H3859, M7177	NHS, BSS	WS
Scirpus atrovirens Willd. (black bulrush); F6121, P44181	BF, NMF, NHS	WS
Scirpus cyperinus (L.) Kunth (wool-grass); F6440, M7284, P44099, P44132, P44163	BF, NHS, BSS	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Scirpus microcarpus J. Presl & C. Presl (panicled bulrush); *Allen s.n., Gerst s.n., Koch 12276*	WC, W-NF	
Trichophorum alpinum (L.) Pers. (alpine bulrush); A2613, F6462	W-NF	
ERIOCAULACEAE (Pipewort Family)		
Eriocaulon aquaticum (Hill) Druce (pipewort); *T5542*	AP	
HEMEROCALLIDACEAE (Day-lily Family)		
Hemerocallis fulva (L.) L. (orange daylily); S263	BF	CR
HYDROCHARITACEAE (Frog's-bit Family)		
Elodea canadensis Michx. (common waterweed); F6526, F6552, H3928, M7272, *T5165, T5275, T5294*	AP	
Elodea nuttallii (Planch.) H. St. John (slender waterweed); *Ts.n.*	AP	
Najas flexilis (Willd.) Rostk. & Schmidt (slender naiad); H3633, S226	AP	
Vallisneria americana Michx. (eel-grass); F6551, M7275, *Ts.n.*	AP	
IRIDACEAE (Iris Family)		
**Iris pseudacorus* L. (yellow-flag); S143	AP, W-NF	
Iris versicolor L. (wild blue-flag); F6386, F6441, M6840, M6976, M7245, M7252, P44081, P44128, *T5266, T5556*	AP, W-NF	
Sisyrinchium montanum Greene (mountain blue-eyed grass); P44019, P44020, *T5481*	PB	
JUNCACEAE (Rush Family)		
Juncus balticus Willd. (arctic rush); *Lahti 80*	AP	
Juncus brachycephalus (Englem.) Buchenau (small headed rush); F6521	WC, BSS, W-NF	
Juncus brevicaudatus (Englem.) Fernald (narrow-panicle rush); F6467, H3700, P44203	WC, AP, W-NF	WS
Juncus effusus L. (soft-stem rush); F6478, H3974, M6991, M7294	NHS, BSS, WC	WS
Juncus greenei Oakes & Tuck (Greene's rush); H2724, H3996	WC	WS
Juncus interior Wiegand (inland rush); *Fields 108*	D	
Juncus nodosus L. (joint rush); H3995, M7298	AP	
Juncus tenuis Willd. (path rush); S199, *T5197*	BF, NDF, NMF	
Juncus vaseyi Engelm. (Vasey's rush); *Judziewicz 11717*	W-NF	SC
Luzula acuminata Raf. (hairy wood rush); F5611, M6642, P43755	BF, NDMF, NMF	
Luzula multiflora (Ehrhart) Lej. (common wood rush); P43789, S42	BF, NDF	WS
LILIACEAE (Lily Family)		
Erythronium americanum Ker Gawl. (yellow trout lily); P43781, S47	BF	WS

Lilium michiganense Farw. (Michigan Lily); F6035	BF, NHS	
Lilium philadelphicum L. (wood lily); M6735, *T5369, T5379*	PB	
ORCHIDACEAE (Orchid Family)		
Arethusa bulbosa L. (dragon's mouth); S184	WC	
Calopogon tuberosus (L.) Britton, Sterns & Poggenb. (grass pink); *Ts.n.*	W-NF	
Calypso bulbosa (L.) Oakes (fairy slipper); Photo	WC	END
Corallorhiza maculata (Raf.) Raf. (spotted coral-root); F6415, *Ts.n.*	BF, NDMF	
Corallorhiza trifida Châtel (early coral-root); M6675, M7058, P44108, S178	WC, NHS	
Cypripedium acaule Aiton (moccasin flower); F6430, M6825, M7016, P44137, *T5402*	WC	
Cypripedium parviflorum Salisb. var. *makasin* (Farw.) Sheviak (small yellow lady's slipper); F6369	WC	SC
Cypripedium parviflorum Salisb. var. *pubescens* (Willd.) O. W. Knight (yellow lady's slipper); Photo	WC	
Cypripedium reginae Walter (showy lady's slipper); P43876	BF	SC
Goodyera pubescens (Willd.) R. Br. (downy rattlesnake plantain); *Gockman s.n.*	NDF	
Goodyera repens (L.) R. Br. (creeping rattlesnake plantain); H3553, M6851, *T5078*	NDMF	
Goodyera tesselata Lodd. (tesselated rattlesnake plantain); H3480, M7214	PB, NDMF	
Malaxis unifolia Michx. (green adder's mouth); *T5396, T5408*	WC	
Neottia cordata (L.) Rich. (heart-leaved twayblade); A2442, F5623, M6674	WC	
Platanthera aquilonis Sheviak (northern green orchid); M6828, M6902	WC	WS
Platanthera clavellata (Michx.) Luer (club-spur orchid); *Judziewicz 11977, Nekola s.n.*	WC	
Platanthera huronensis (Nutt.) Lindl. (green bog orchid); P44110, P44143, S175, *T5353*	NHS	
Platanthera obtusata (Pursh) Lindl. (blunt-leaved orchid); F6368, M6830, S212, *T5105, T5385, T5558*	WC	
Platanthera psycodes (L.) Lindl. (purple fringed orchid); M7246, S262	W-NF	
Pogonia ophioglossoides (L.) Ker Gawl. (rose pogonia); F6466	W-NF	
Spiranthes lacera (Raf.) Raf. (northern slender lady's tresses); H4093	PB	
POACEAE (Grass Family)		
**Agrostis gigantea* Roth (red top); H3671, M7112, *T5143, T5530*	PB, NDMF, NMW	
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb. (tickle grass); *T5410, T5411, T5679*	PB, NDF	
Agrostis perennans (Walter) Tuck. (autumn bent grass); F6141, M6837, M6881, P44162, *T5480*	BF, NDMF	
Agrostis scabra Willd. (rough bent grass); A2485, F6544, M6754, M6784, M7159, M7303	PB	
**Agrostis stolonifera* Willd. (creeping bent grass); H2811	W-NF	WS
Alopecurus aequalis Sobol. (short-awned foxtail); *T5533*	W-NF	
**Alopecurus pratensis* L. (meadow foxtail); M6997, S53	NHS	WS
Ammophila breviligulata Fernald (beach grass); *Castle 92-18*	LSS	

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Andropogon gerardii Vitman (big bluestem); M6782, M7219, P43888, *T5072*	PB, NDF	
**Anthoxanthum odoratum* L. (sweet vernal grass); H4290, *Clark 1260*	D	
Aristida basiramea Vasey (fork-tipped three-awn grass); M6802, P43890	PB	
Brachyelytrum aristosum (Michx.) Branner & Coville (long-awned wood grass); F6501, M6703, M6883, M7037, M7093	BF, NDMF, NMF	WS
Bromus ciliatus L. (fringed brome); F6042, F6088, F6488, M6708, M6886, M7106, M7220, P44104, P44151, P44180	BF, NDMF, NMF	
**Bromus inermis* Leyss. (smooth brome); S137, S279, *T5217*	D	
Bromus kalmii A. Gray (prairie brome); A2490, M6739, M6787, M7218, P44012	PB, NDF, NDMF	
Bromus latiglumis (Shear) Hitchc. (hairy wood brome); H3674	NDF	CR
Bromus pubescens Spreng. (Canadian brome); H3371, H3720	BF, LNHS, NMF	
Calamagrostis canadensis (Michx.) P. Beauv. (blue-joint grass); F6091, F6149, F6388, F6417, F6426, F6592, M6841, M6879, M6966, M7285, P44083	BF, W-NF, NHS	
Cinna arundinacea L. (common wood reed); F6491, H3611	NDMF, NHS	CR
Cinna latifolia (Goepp.) Griseb. (wood reed grass); F6103, M6821, M6871	BF, NMF, NHS	
**Dactylis glomerata* L. (orchard grass); S116, *T5267*	NMF	
Danthonia spicata (L.) Roem. & Schult. (poverty oat grass); M6731, M6741, M6742, M6815, M7097, P44007, *T5412, T5532, T5536*	PB, NDF, NDMF	
Dichanthelium acuminatum (Sw.) Gould & C. A. Clark (hairy panic grass); H4005, M7146, P44040, P44170	PB, NDF, NDMF	
Dichanthelium columbianum (Scribn.) Freckmann (hemlock panic grass); *T5409*	PB	
Dichanthelium depauperatum (Muhl.) Gould (starved panic grass); M6755, P44021, P44056, *T5216, T5529*	PB, NDF	
Dichanthelium linearifolium (Scrib.) Gould (linear-leaved panic grass); H4028, M7147	PB	CR
Dichanthelium meridionale (Ashe) Freckmann (mat panic grass); H4006, M6748	PB	WS
Dichanthelium oligosanthes (Schult.) Gould (red dot panic grass); H3669	NMF	CR
Dichanthelium xanthophysum (A. Gray) Freckmann (slender rosette grass); A2605, M6807, M7154, P43852, P44033, P44166, *T5553*	PB, NDF, NDMF	
**Digitaria ischaemum* (Schreb.) Muhl. (smooth crabgrass); P43892	PB	WS
**Echinochloa crusgalli* (L.) P. Beauv. (barnyard grass); *T5534*	PB	
Echinochloa muricata (P. Beauv.) Fernald (barnyard grass); H3483, *T5103, T5534*	PB	
Elymus canadensis L. (Canada wild rye); S256	LSS	
Elymus hystrix L. (bottlebrush grass); F6014, F6057, F6114, F6493, P43880, P44173, *T5276*	BF, NDF, NMF	

**Elymus repens* (L.) Gould (quack grass); H3655, *T5526*	PB, NDMF	
Elymus trachycaulus (Link) Gould (slender wheat grass); F6058, H3735, M6811, M7136, S153, S257	BF, PB, NMF	
Elymus virginicus L. (Virginia wild rye); H3970, F6106, P43879	BF, NHS	
Elymus wiegandii Fernald (Wiegand's wild rye); F6577, P43878	BF	CR
Eragrostis hypnoides (Lam.) Britton, Sterns & Poggenb. (creeping love grass); *T5344*	LSS	
Festuca saximontana Rydb. (Rocky Mountain fescue); H4058, M6692	PB, NDMF	WS
Festuca subverticillata (Pers.) E.B.Alexeev (nodding fescue); M7137	NMF	WS
**Festuca trachyphylla* (Hack.) Krajina (hard fescue); H3680	PB, NDF, NHS	WS
Glyceria borealis (Nash) Batch. (northern manna grass); F6385, F6533, H3793, M7283	NHS, AP	
Glyceria canadensis (Michx.) Trin. (rattlesnake grass); F6457, M7164, M7234, M7250, P44076, P44134, P44209	NHS, BSS	
Glyceria grandis S. Watson (reed manna grass); H3625, *T5481*	NHS, W-NF	
Glyceria striata (Lam.) Hitchc. (fowl manna grass); F6021, F6504, F6518, M6959, M7055	BF, WC, W-NF	
Koeleria macrantha (Ledeb.) Schult. (June grass); H4030, P44010, *T5528*	PB, NDF	
Leersia oryzoides (L.) Sw. (rice cut grass); F6548, H3860, M7282, *T5487*	NHS, AP	
Milium effusum L. (wood millet); F6031, F6099, M7051, F6505, *T5534*	BF, NMF	
Muhlenbergia glomerata (Willd.) Trin. (marsh muhly); M7215, P43853, P43913	PB, NDMF	WS
Muhlenbergia mexicana (L.) Trin. (leafy satin-grass); M6779, P43882, P44177	PB, NDF, NDMF	WS
Oryzopsis asperifolia Michx. (rough-leaved rice grass); F6318, M6688, P43771, *T5224, T5225*	BF, NDMF, NMF	
**Phalaris arundinacea* L. (reed canary grass); F6564	W-NF, NHS, NMF	
**Phleum pratense* L. (Timothy); H4025, *T5525*	BF, NDF, PB	
Piptatherum pungens (Spreng.) Dorn (mountain rice grass); H4036, M6694	PB	WS
Poa alsodes A. Gray (woodland bluegrass); H4037, M7049	NHS	WS
**Poa annua* L. (annual bluegrass); *Gilbert s.n.*	BF, NDF	
**Poa compressa* L. (Canada bluegrass); H3681, S147	BF, PB, NDMF	WS
**Poa nemoralis* L. (wood bluegrass); F6036, F6052, F6329, P43849	BF, NDF, NDMF	WS
Poa palustris L. (marsh bluegrass); F6030, F6498, P44048, S70, *T5527, T5535*	WC, NHS	
**Poa pratensis* L. (Kentucky bluegrass); F6316, F6341, H4027, M6690	BF, NHS, NMF	WS
Poa saltuensis Fernald & Wiegand (old pasture bluegrass); F6326, F6329, H4013, M7015, M7065	WC, NMF	
Schizachne purpurascens (Torr.) Swallen (false melic grass); F6317, H3405, M7067, P44005, *T5506*	BF, PB, NDMF	
Schizachyrium scoparium (Michx.) Nash (little bluestem); M6786, P43896, *T5073*	PB	
**Setaria pumila* (Poir.) Roem. & Schult. (yellow foxtail); H3485	D	WS
Sorghastrum nutans (L.) Nash (Indian grass); P43922	PB	
Spartina pectinata Link (prairie cord grass); P43886	BF	WS

(*Continued on next page*)

APPENDIX 1. (Continued)

Taxon	Habitat	Status
Sphenopholis intermedia (Rydb.) Rydb. (slender wedge grass); A2600, M6724	BF, NMF	WS
Torreyochloa pallida (Torrey) Church (pale false manna grass); P44078	W-NF	CR
Zizania palustris L. (northern wild rice); S253	AP	
PONTEDERIACEAE (Pickerel-weed Family)		
Heteranthera dubia (Jacq.) Macmill. (water star grass); H3643, M7313, M7318, S224	AP	WS
POTAMOGETONACEAE (Pondweed Family)		
Potamogeton alpinus Balb. (alpine pondweed); H3768, H3892, H3956, S231, *T5088, T5262, T5280, T5347*	AP	
Potamogeton amplifolius Tuck. (large-leaved pondweed); S220	AP	
Potamogeton berchtoldii Fieber (slender pondweed); H3923	AP	
Potamogeton epihydrus Raf. (ribbon leaf pondweed); F6545, F6588, H3694, H3698, H3851	AP	
Potamogeton foliosus Raf. (leafy pondweed); H3693, H3637, M7293, S230, S246, *T5297, T5486*	AP	
Potamogeton friesii Rupr. (Fries's pondweed); F6519	AP	
Potamogeton gramineus L. (variable leaf pondweed); F6545, H3785, H3647, S227, *T5346, T5234*	AP	
Potamogeton illinoensis Morong (Illinois pondweed); H4066, M7274	AP	WS
Potamogeton natans L. (floating-leaf pondweed); F6524, H3634, H3696, M7310, *T5279, T5361*	AP	
Potamogeton nodosus Poir. (long-leaf pondweed); H3788	AP	CR
Potamogeton oakesianus J.W. Robbins (Oakes' pondweed); P44198, P44218	AP	CR
Potamogeton obtusifolius Mert. & W.D.J.Koch (blunt-leaf pondweed); M7273, *Ts.n.*	AP	
Potamogeton praelongus Wulfen (white-stemmed pondweed); H3636, H4294, *T5164, T5270*	AP	
Potamogeton pusillus L. (small pondweed); F6539, H4293, P44217, *T5278*	AP	WS
Potamogeton richardsonii (A. Benn.) Rydb. (Richardson's pondweed); F6558, F6589, F6016, M7290, *T5167, T5168, T5276*	AP	
Potamogeton robbinsii Oakes (Robbin's pondweed); H3574, H3787	AP	
Potamogeton spirillus Tuck. (spiral pondweed); S225, S228, S229, S235, S244	AP	
Potamogeton strictifolius A. Benn. (narrow-leaved pondweed); H3915, *T5296*	AP	
Potamogeton zosteriformis Fernald (flat-stemmed pondweed); H3762, H3914, F6529, *T5274, T5299*	AP	
Stuckenia filiformis (Pers.) Börner (narrow-leaved pondweed); *Alverson 1803a*	AP	
Stuckenia pectinata (L.) Börner (sago pondweed); H3767, H3960, F6590, F6591, *T5271, T5172, T5175, T5277, T5285, T5511*	AP	
SCHEUCHZERIACEAE (Pod-grass Family)		
Scheuchzeria palustris L. (pod-grass); F6436, M7184, P44074, P44120	WC, W-NF	WS

SMILACACEAE (Carrion Flower Family)		
Smilax illinoensis Mangaly (Illinois carrion-flower); P43775.2	BF	CR
Smilax lasioneura L. (bristly greenbrier); H3840	BF	WS
TRILLIACEAE (Trillium Family)		
Trillium cernuum L. (nodding trillium); F5639, F6096, F6320, M6718, M6875, M6984, P43770, *T5420, T5562*	BF, NDMF, NMF	
Trillium grandiflorum (Michx.) Salisb. (big white trillium); S64	BF, WC	WS
TYPHACEAE (Cat-tail Family)		
Sparganium americanum Nutt. (American bur-reed); F6557	AP	
Sparganium angustifolium Michx. (narrow-leaved bur-reed); S238, *Ts.n.*	AP	
Sparganium emersum Rehm. (green-fruited bur-reed); S237, S251, *T5490, T5512*	AP	
Sparganium eurycarpum Engelm. (common bur-reed); H4152, *T5493*	AP	
Sparganium fluctuans (Morong) B. L. Rob. (floating bur-reed); H3644, H3786, H3930, S241, *T5489*	AP	
**Typha angustifolia* L. (narrow-leaved cat-tail); F6528, H3775, M7316	AP	WS
Typha latifolia L. (common cat-tail); M7317, *T5352*	AP	
**Typha* × *glauca* Godr. (hybrid cat-tail); H3920	AP	WS

APPENDIX 2. Prevalent ground layer species in each forest community type. Frequency of occurrence is the percentage of sites within the forest community type in which the species occurs. Frequency of common occurrence is the percentage of sites within the forest community type in which the species is widely distributed.

Species	Frequency of occurrence	Frequency of common occurrence
Boreal Forest		
Eurybia macrophylla	100	100
Rubus parviflorus	100	100
Maianthemum canadense	100	90
Pteridium aquilinum	100	80
Aralia nudicaulis	80	100
Cornus canadensis	100	50
Carex gracillima	100	50
Athyrium filix-femina	90	67
Cornus sericea	90	56
Equisetum arvense	90	56
Anemone quinquefolia	80	63
Calamagrostis canadensis	80	50
Northern Wet-Mesic Forest		
Rubus pubescens	100	100
Coptis trifolia	100	100
Maianthemum canadense	100	91
Trientalis borealis	100	82
Cornus canadensis	100	82
Clintonia borealis	100	64
Gaultheria hispidula	100	64
Mitella nuda	100	55
Osmunda cinnamomea	100	55
Aralia nudicaulis	91	50
Orthilia secunda	91	50
Carex disperma	82	56
Pine Barrens		
Comptonia peregrina	100	100
Corylus americana	100	100
Prunus pumila	100	100
Rubus flagellaris	100	100
Carex pensylvanica	100	100
Vaccinium angustifolium	100	100
Quercus macrocarpa	100	83
Quercus ellipsoidalis	100	83
Andropogon gerardii	83	100
Danthonia spicata	83	100
Monarda fistulosa	83	80
Hieracium aurantiacum	100	50
Solidago nemoralis	100	50
Schizachyrium scoparium	100	50
Arctostaphylos uva-ursi	83	60
Bromus kalmii	83	60

(*Continued on next page*)

APPENDIX 2. (Continued)

Species	Frequency of occurrence	Frequency of common occurrence
Northern Dry Forest		
Maianthemum canadense	100	100
Pteridium aquilinum	100	100
Oryzopsis asperifolia	80	80
Carex pensylvanica	100	60
Eurybia macrophylla	100	60
Rubus allegheniensis	100	60
Uvularia sessilifolia	100	60
Northern Dry Mesic Forest		
Maianthemum canadense	100	100
Pteridium aquilinum	100	100
Aralia nudicaulis	100	83
Eurybia macrophylla	100	83
Oryzopsis asperifolia	100	67
Clintonia borealis	100	50
Lonicera canadensis	100	50
Northern Hardwood Swamp		
Carex stipata	100	100
Rubus pubescens	100	86
Glyceria striata	86	86
Carex intumescens	100	71
Carex gracillima	100	57
Onoclea sensibilis	100	56
Carex projecta	86	71
Northern Mesic Forest		
Acer saccharum (seedlings)	100	89
Maianthemum canadense	100	89
Clintonia borealis	89	88
Carex pensylvanica	100	67
Aralia nudicaulis	100	56
Quercus rubra (seedlings)	89	78
Northern Wet Forest		
Rhododendron groenlandicum	100	100
Maianthemum trifolium	100	83
Carex trisperma	100	66
Vaccinium angustifolium	100	50

APPENDIX 3. Summary of data for the eight forest community types. Major tree dominants are derived from importance values in the *Forest stand changes in the Bois Brule River 1968 to 2016* (Hlina et. al. 2020). Leading families are the percentage of all species in the forest community type that are in that family.

Category	Data
Boreal Forest	
Major tree dominants	*Populus tremuloides*, *Abies balsamea*, *Picea glauca*, *Pinus strobus*
Most prevalent ground layer species	*Eurybia macrophylla*, *Maianthemum canadense*, *Pteridium aquilinum*, *Aralia nudicaulis*
Leading families	Cyperaceae (10.1%), Asteraceae (9.6%), Rosaceae (8.0%), Poaceae (7.4%) Ranunculaceae (5.3%)
Average species richness	132
Total species richness	362
Ct	4.5
Cn	5.3
Non-native species (%)	14.9%
Growth form counts	Trees (26), Shrubs (50), Forbs (208), Graminoids (64), Vines (6)
Northern Wet-Mesic Forest	
Major tree dominants	*Thuja occidentalis, Abies balsamea*
Most prevalent ground layer species	*Rubus pubescens, Coptis trifolia, Maianthemum canadense, Trientalis borealis, Cornus canadensis*
Leading families	Cyperaceae (10.8%), Asteraceae (9.9%), Rosaceae (7.9%), Poaceae (5.8%) and Ericaceae (5.3%)
Average species richness	98
Total species richness	299
Ct	5.8
Cn	6.1
Non-native species (%)	4.3%
Growth form counts	Trees (18), Shrubs (48), Forbs (142), Graminoids (51), Vines (1)
Pine Barren	
Major tree dominants	*Pinus banksiana, Pinus resinosa*
Most prevalent ground layer species	*Comptonia peregrina, Corylus americana, Prunus pumila, Rubus flagellaris, Carex pensylvanica, Vaccinium angustifolium, Quercus macrocarpa, Quercus ellipsoidalis, Andropogon gerardii, Danthonia spicata, Monarda fistulosa*
Leading families	Asteraceae (17.8%), Poaceae (12.0%), Rosaceae (11.6%)
Average species richness	79
Total species richness	207
Ct	4.1
Cn	4.8
Non-native species (%)	16.4%
Growth form counts	Trees (12), Shrubs (27), Forbs (118), Graminoids (32), Vines (1)

APPENDIX 3. (*Continued*)

Category	Data
Northern Hardwood Swamp	
Major tree dominants	*Fraxinus nigra, Thuja occidentalis*
Most prevalent ground layer species	*Carex stipata, Alnus incana, Rubus pubescens, Glyceria striata*
Leading families	Cyperaceae (15.9%), Asteraceae (11.4%), Poaceae (10.6%) and Rosaceae (9.3%).
Average species richness	92
Total species richness	307
Ct	5.0
Cn	5.6
Non-native species (%)	10.7%
Growth form counts	Trees (19), Shrubs (43), Forbs (164), Graminoids (75), Vines (6)
Northern Dry Forest	
Major tree dominants	*Pinus resinosa*
Most prevalent ground layer species	*Maianthemum canadense, Pteridium aquilinum, Oryzopsis asperifolia*
Leading families	Asteraceae (11.7%), Rosaceae (11.2%), Poaceae (11.2%), Cyperaceae (6.6%) and Ericaceae (6.1%)
Average species richness	75
Total species richness	209
Ct	4.4
Cn	5.2
Non-native species (%)	15.8%
Growth form counts	Trees (14), Shrubs (42), Forbs (104), Graminoids (33), Vines (4)
Northern Dry Mesic Forest	
Major tree dominants	*Pinus resinosa, Abies balsamea, Pinus strobus*
Most prevalent ground layer species	*Maianthemum canadense, Pteridium aquilinum, Aralia nudicaulis, Eurybia macrophylla*
Leading families	Asteraceae (11.3%), Rosaceae (9.2%), Poaceae (8.3%), Cyperaceae (5.4%) and Ericaceae (5.4%)
Average species richness	94
Total species richness	263
Ct	5.5
Cn	4.8
Non-native species (%)	12.9%
Growth form counts	Trees (27), Shrubs (38), Forbs (133), Graminoids (35), Vines (7)

(*Continued on next page*)

APPENDIX 3. (*Continued*)

Category	Data
Northern Mesic Forest	
Major tree dominants	*Acer saccharum, Tilia americana, Acer rubrum*
Most prevalent ground layer species	*Acer saccharum, Maianthemum canadense, Clintonia borealis*
Leading families	Cyperaceae (10.7%), Poaceae (9.4%), Asteraceae (9.0%), Rosaceae (7.7%), Ranunculaceae (5.6%) and Liliaceae (3.4%)
Average species richness	85
Total species richness	242
Ct	5.2
Cn	5.4
Non-native species (%)	10%
Growth form count	Trees (20), Shrubs (37), Forbs (125), Graminoids (50), Vines (2)
Northern Wet Forest	
Major tree dominants	*Picea mariana, Larix laricina*
Most prevalent ground layer species	*Rhododendron groenlandicum, Maianthemum trifolium*
Leading families	Cyperaceae (19.0%), Ericaceae (13.1%), Asteraceae (6.4%), Rosaceae (6.0%), and Poaceae (4.8%)
Average species richness	36
Total species richness	156
Ct	5.7
Cn	6.1
Non-native species (%)	6.4%
Growth form count	Trees (10), Shrubs (22), Forbs (31), Graminoids (21), Vines (0)

INSTRUCTIONS TO AUTHORS

Refer to http://quod.lib.umich.edu/m/mbot/submit for more detailed instructions, especially for formatting, style conventions, literature cited, and voucher specimen requirements. Please contact the editor with any questions.

1. Create text in 12-point Times New Roman font and double space paragraphs throughout. Research articles should be organized as follows: Title, Author(s) and address(es), Abstract with up to 5 keywords, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, Literature Cited, Tables, Figure Legends, and Figures. Sections may be omitted if not relevant. All pages should be numbered.

2. For noteworthy collections, manuscripts should be formatted as follows. The title, "Noteworthy Collections," should begin each submitted manuscript, followed on the next line by the State or Province for the species reported. The next line should list the taxon of interest using the following format: Species Author(s) (Family). Common name. The rest of the manuscript should include the following named sections: (i) Significance of the Report, (ii) Previous Knowledge, (iii) Discussion, (iv) Diagnostic Characters (if desired), (v) Specimen Citations, (vi) Acknowledgements (if desired), and (vii) Literature Cited. Each of these sections is largely self-explanatory; however, the "Significance of the Report" section should be limited to a brief sentence or phrase indicating the significance of the collection(s), and this may be expanded upon in the "Discussion" section; the "Specimen Citations" section should include the relevant label data from the voucher specimen(s) including location data, collector(s), collection number, etc., as well as the Index Herbariorum acronym(s) of the herbarium or herbaria where the specimen(s) are deposited. The manuscript should end with the name and address of the author(s).

3. Non-research articles, such as book reviews, letters to the editor, notices, biographies and other general interest articles can be formatted as general text without the specific sections listed above. However, literature cited and any tables or figures should be formatted as described below.

4. Create tables as a MS Word table. Each table is to be submitted as a separate file. Table captions should be placed at the top of the table. Any footnotes should appear at the bottom of the table. Please do not insert tables within the body of the text.

5. Send each figure as a separate file in a high-resolution format—eps, jpg, or tif. Figures like bar graphs that gain their meaning with color won't work—use coarse-grained cross-hatching, etc. Create figure legends as a separate text file, and the typesetter will insert them as appropriate. Please do not insert the figure in the body of the text file.

6. Citations: Please verify that all references cited in the text are present in the literature cited section and vice versa. Citations within the text should list the author's last name and publication year (e. g. Smith 1990). For works with more than 2 authors, use "et al.", and separate multiple citations with a semicolon.

7. Literature Cited: List citations alphabetically by author's last name. The first author's name is to be listed with surname first, followed by initials (e.g. Smith, E. B.), and subsequent authors are to be listed with initials first.Separate author's initials with a single space. The year of publication should appear in parentheses immediately before the title of the citation. The entire journal name or book title should be spelled out. Please put a space after the colon when citing volume number and page numbers.

8. Italicize all scientific names. Voucher specimens must be cited in floristic works and in any other study whose results depend on the identity of the plant(s). Papers citing plant records without documenting vouchers are generally not acceptable.

9. Manuscripts must be submitted electronically to the email address of the editor. All manuscripts will be reviewed by at least two referees.

CONTENTS

Articles

The Great Lakes Botanist Vol. 59, Nos. 1–2 January–July 2020

On the cover: Mays Ledges (Class II–III) on the Bois Brule River, Douglas County, Wisconsin. Photo by Derek S. Anderson

May Ledges is a series of rocks and ledges in the lower reaches of the river and is a favorite among canoe and kayak enthusiasts that is often rated as one of the best white-water experiences in Wisconsin. The river in this section falls 100 m in the last 29 km to Lake Superior.

In 1680, Daniel Greysolon Sieur du Lhut was the first voyageur to make his way up the Bois Brule River and the St. Croix River, seeking a waterway to the Mississippi. This early exploration confirmed that a waterway passage existed between the Upper Great Lakes and the center of the continent. In the ensuing centuries, new explorers traveled these waters describing the geology, vegetation, and character of the river. In 1845, Morgan Lewis Martin published in the St. Croix Falls *Daily Union* the following early account of one early exploration originating at La Pointe, Madeline Island, and continuing to the Mississippi. Morgan has just entered the river from the mouth, when he begins his narrative. The italicized section is one of the early accounts of Mays Ledges.

> After going three or four miles, we struck the rapids of this river, over the trap boulders of which the water dashed like a mill-tail. Our voyageurs had to poke up them with all the strength and skill they could command, for there was constant danger of the canoes being dashed and stove against the rocks, or of being suddenly thrown across the current and capsized. These rapids were flanked at either side with red sand-stone cliffs; and the darkest and thickest kind of growth, composed of silver fur, or Canadian balsam, white cedars, birch, &c., and wholly unfit for tillage.
>
> We worked forward in this way over rapids, for about thirty miles; and having passed three portages, around which we had to walk and carry our baggage, with still the fourth and last severe one before us, we finally struck up a camp near the head of the third portage, where all were sufficiently fatigued to sleep most soundly. *At this last portage rapid, there appeared in the bottom of the river a mass of trap crossing it, over which the water fell two or three feet nearly perpendicular.*